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MEETING OF THE BRITISH ASSOCIATION AT ABERDEEN.

THE dignified and thriving Scottish city, a seat of learning and of commerce, where the British Association for the Advancement of Science holds its annual Congress this year, ranks next after Edinburgh and Glasgow in importance among the towns of North Britain, having a population that now approaches 100,000. It is situated on the north bank of the Dee, just above the mouth of that river, the issue of which into the German Ocean has been slightly diverted by works enlarging the harbor and giving space for the construction of commodious docks. The older part of the town, containing the principal business streets and public buildings, occupies a range of hills, to the west of which, across the valley of the Den burn, is the New Town, joined to the other part by a fine bridge of 132 ft. span, 50 ft. above the valley, carrying the broad straight thoroughfare of Union street nearly on the same level.

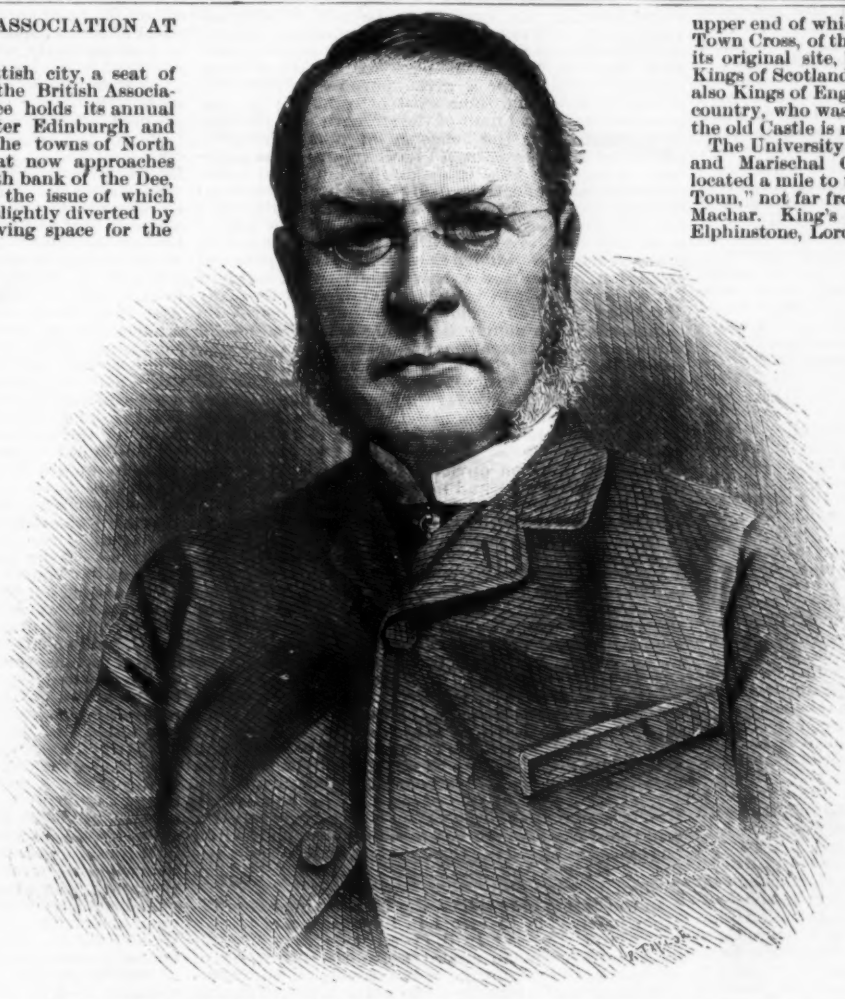
The central railway station, like the Waverley station at Edinburgh, lies in the valley between the Old and New Towns, but is close to the docks, and about a mile from the sea. Union street, nearly a mile long, has a rather grand appearance, the houses being mostly large and built of gray granite; at the upper end, it widens into Castle street, of which we give an illustration; here are the Municipal and County Buildings, a very fine edifice of Scottish baronial architecture, turreted at the angles and in the main facade, with a tower 200 ft. high, and with massive columns upholding the elliptical arches; there is another tower, with a spire, at the east end.

The interior, with the great hall, timber roofed and oak paneled, the Town Hall, the County Hall, the Court rooms, and various offices, is stately and convenient; the architects were Messrs. Peddie and Kinnear, of Edinburgh. Several banks and other important buildings stand in or near Castle street, the upper end of which is further adorned with an ancient Town Cross, of the seventeenth century, removed from its original site, bearing medallion portraits of the Kings of Scotland, including those Stuarts who were also Kings of England, down to James II. of the one country, who was James VII. of the other. The site of the old Castle is now occupied by military barracks.

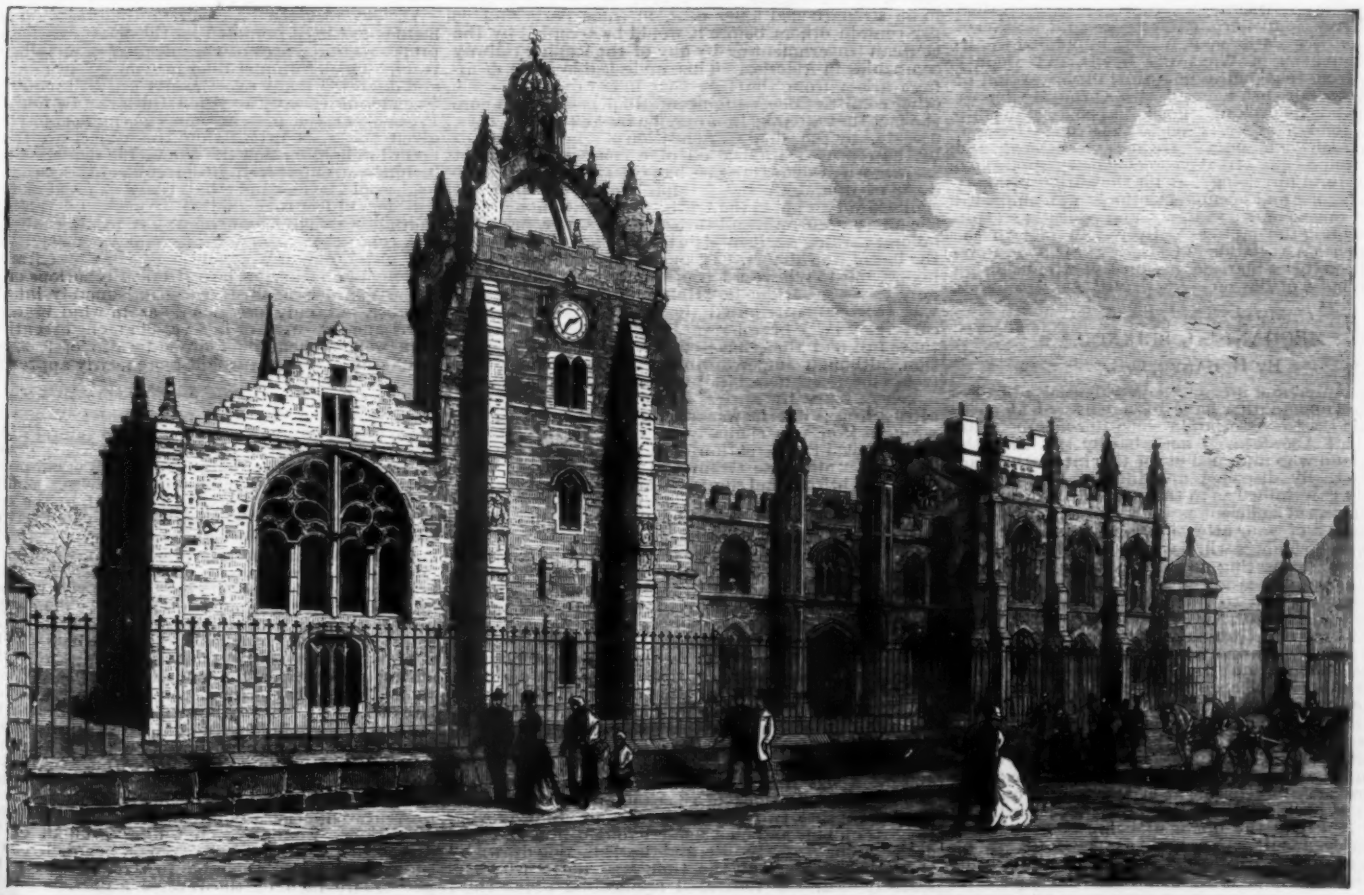
The University of Aberdeen includes King's College and Marischal College. The former institution is located a mile to the north, in the Spittal of the "Auld Toun," not far from the venerable Cathedral of St. Machar. King's College, founded in 1495 by Bishop Elphinstone, Lord Chancellor of Scotland, is a quadrangle of collegiate residences, with chapel and library, surmounted by a tall lantern spire with a crown at the top. Marischal College, founded by George Keith, Earl Marshal, in 1593, on the site of a Franciscan monastery, is in Broad street, close to Castle street, and has been rebuilt, of granite, in a handsome style, but is too much crowded on by other houses.

A tower, 100 ft. high, rises at one side of the quadrangle, where is the principal entrance, with a staircase leading to the hall, library, and museum. A curious old inscription at the entrance has been preserved, which runs thus in the ancient Scottish dialect, "Thay haif said: Quhat say thay: Lat them say." In the square is a granite obelisk, 70 ft. high, to the memory of Sir James Macgregor, Director-General of the Army Medical Department, who was educated at Marischal College. The two colleges were united in 1860, and the University is in good repute.

On the north side of Aberdeen flows another river, the Don, with a bridge that bears the name of Balgownie, which was formerly of ill-omen. The biography of Lord Byron, part of whose childhood, as a relative of the Gordon family, was spent in this neighborhood, mentions his feelings of superstitious terror, when a little boy, in riding over this bridge on his pony, and remembering the dismal prophecy:



SIR LYON PLAYFAIR, K.C.B., M.P., PRESIDENT OF THE BRITISH ASSOCIATION.



THE UNIVERSITY OF ABERDEEN, THE MEETING PLACE OF THE BRITISH ASSOCIATION.

Brig o' Balgownie, black's your wa';
With a wife's ae son, and a mare's ae foal,
Down ye shall fa'.

The ancient Royal Burgh of Aberdeen has many interesting historical associations; the town is now distinguished for enterprise in trade and industry; its cotton, flax, jute, woolen, and iron manufactures, as well as its shipping, and the working of its famous granites, which furnish architectural and sculptural ornaments to many other towns in Great Britain, employ a great number of workmen. The docks, with an area of thirty-four acres and an entrance 70 ft. wide, as well as the pier and breakwater, have greatly improved the accommodation of the port. Among the local institutions are to be noticed the Royal Infirmary, the Grammar School, the Gordon College, and others devoted to public beneficence, with the agreeable Public Parks. The neighborhood is pleasant for residence, and within a short distance of some of the finest Highland scenery, Deeside, Balmoral, and Braemar.

Sir Lyon Playfair.—The President of the British Association for the Advancement of Science at this year's Congress at Aberdeen is the Right Hon. Sir Lyon Playfair, K.C.B., M.P. for the Universities of Edinburgh and St. Andrew's, and LL.D. of Edinburgh University. He is eminent as a scientific and practical chemist, a sanitary reformer, an educational reformer, a man of public business, an ex-Minister, and late Chairman of the Committee of Ways and Means in the House of Commons. He was born in India, at Meerut, May 21, 1819, being son of Mr. G. Playfair, Chief Inspector-General of Hospitals in Bengal, and nephew to the late Colonel Sir Hugh Playfair, of the East India Company's service. He was educated at St. Andrew's, and studied chemistry under Prof. Graham at Glasgow, and afterward at Giessen under Professor Liebig. He was for some time manager of the calico-printing works of Messrs Thompson, of Clitheroe, but in 1843 was appointed Professor of Chemistry at the Manchester Royal Institution, succeeding Dalton. In the following year, he was appointed by Sir Robert Peel's Government to serve on the Royal Commission of Inquiry concerning the sanitary condition of large towns and populous districts. He afterward came to London, and held the Chemical Professorship of the Museum of Practical Geology. He was specially employed in the arrangements for the Great Exhibition of 1851, visiting the manufacturing districts and drawing up an elaborate scheme of classification of their products, materials, and processes; he was Special Commissioner for the appointment and superintendence of the juries at that exhibition, and again at the Exhibition of 1862. For these services he was nominated C.B., and also received an appointment in the household of the late Prince Consort; he was also made joint Secretary, with Sir Henry Cole, of the Science and Art Department created in 1853, and in 1856 became Inspector-General of the Government Museums and Schools of Science, He was elected, in 1857, President of the Chemical Society of London, and, in the next year, Professor of Chemistry at the Edinburgh University, where the Prince of Wales and Prince Alfred (the Duke of Edinburgh) attended his classes. Among other special inquiries with which he was intrusted by Government were those into the causes of accidents in coal mines, and, jointly with Sir Henry de la Beche, into the qualities of British coal for the use of the navy; the Royal Commission on the Cattle Plague, the Royal Commission on the Scottish Fisheries, and the Civil Service Organization Commission of 1874. He was Chairman of the Finance Committee of the English Commission for the Paris Exhibition of 1878, and is one of the Commissioners of the Board of Manufactures. In 1868, Dr. Lyon Playfair was elected, as a Liberal, to the seat in the House of Commons which he has since retained; he became a member of Mr. Gladstone's Government in 1873, holding the office of Postmaster-General, and was then made a Privy Councilor. After the general election of 1880, in the New Parliament, he was appointed Chairman of Committee of Ways and Means, and Deputy Speaker; from these offices he retired in the session of 1883, and was raised to the rank of K.C.B. He has received the honors of knighthood and commandership of several foreign orders, French, Austrian, German, Swedish, and Portuguese. He has translated and edited Baron Liebig's treatise on chemistry applied to agriculture and physiology, and is the author of many scientific reports and memoirs, lectures, and published addresses, on economic, sanitary, and educational subjects, including the address delivered in 1874 to the Social Science Association at Glasgow. Sir Lyon Playfair has been thrice married, his present wife being an American lady, of Boston.—*Illustrated London News.*

MECHANICAL SCIENCE.*

By B. Baker, C.E.

Two hundred and fifty-seven presidential addresses of one kind and another have been delivered at meetings of the British Association since the members last mustered at Aberdeen. I need hardly say that the candid friend who informed me of this interesting fact most effectually dispelled any illusion I may have previously entertained as to the possibility of preparing an address of sufficient novelty and suggestiveness to be worthy of your attention, and I can only hope that any shortcomings will be dealt with leniently by you. One compensating advantage obviously belongs to my late appearance in the field—I have 257 models of style upon which to frame my address. My distinguished predecessor, Sir Frederick Bramwell, has a style of his own, in which wit and wisdom are combined in palatable proportions; but were I to attempt this style, I should doubtless incur the rebuke which a dramatic critic of Charles the Second's time administered to a too ambitious imitator of a popular favorite: "He's got his fiddle, but not his hands to play on't." I must search further back than last year, therefore, for a model of style, and the search reminds me that I labor under a double disadvantage: first, that only two addresses intervene between the present one and that of my partner, Mr. John Fowler, with whom I have so long had the honor of being associated, and whose professional experiences, as set forth in his address, are necessarily so largely identical with my own; and, secondly, that within the same period I have read before this Section two somewhat lengthy papers on the work which is at present chiefly engaging the attention of Mr. Fowler and myself—the great Forth Bridge.

Although, for the reasons aforesaid, I am conscious that my address may fail in novelty, I cannot honestly profess to feel a difficulty in preparing an address of some kind, for the subjects embraced under the head of "Mechanical Science" are so inexhaustible that even the youngest student might safely accept the responsibility of speaking for an hour on some of them. Prof. Rankine, addressing you thirty years ago, said it was well understood that questions of pure or abstract mechanics form no part of the subjects dealt with in this Section. With characteristic clearness of conception and precision of language he told you what the term "Mechanical Science" meant, and, after thirty years' interval, his words may be recalled with advantage to every one proposing to prepare an address or report for this Section. "Mechanical science," said Prof. Rankine, "enables its possessor to plan a structure or machine for a given purpose without the necessity of copying some existent example; to compute the theoretical limit of the strength and stability of a structure or the efficiency of a machine of a particular kind; to ascertain how far an actual structure or machine fails to attain that limit, and to discover the cause and the remedy of such shortcoming; to determine to what extent, in laying down principles for practical use, it is advantageous for the sake of simplicity to deviate from the exactness required by pure science; and to judge how far an existing practical rule is founded on reason, how far on custom, and how far on error." There is thus an ample text for many discourses; but, as I am not writing a treatise on engineering, but merely delivering a brief address, I will confine my attention at present to a particular case of the branch of mechanical science referred to in the last clause of Prof. Rankine's definition, and will ask you to consider how far the existing practical rules respecting the strength of metallic bridges are "founded on reason, how far on custom, and how far on error."

The first question obviously is, What are the rules adopted by engineers and government departments at the present time?—and it is one not easily answered. I have for some time past been receiving communications from leading Continental and American engineers, asking me what is my practice as regards the admissible intensity of stress on iron and steel bridges, and in replying I have invited similar communications from themselves. As a result, I am able to say that at the present time absolute chaos prevails. The old foundations are shaken, and engineers have not come to any agreement respecting the rebuilding of the structure. The variance in the strength of existing bridges is such as to be apparent to the educated eye without any calculation. If the wheels of a miniature brougham were fitted to a heavy cart, the incident would excite the derision even of our street boys, and yet equal want of reason and method is to be found in hundreds of bridges in all countries. It is an open secret that nearly all the large railway companies are strengthening their bridges, and necessarily so, for I could cite cases where the working stress on the iron has exceeded by 250 per cent. that considered admissible by leading American and German bridge-builders in similar structures.

In the case of old bridges, the variance in strength is often partly due to errors in hypothesis and miscalculation of stresses. In the present day, engineers of all countries are in accord as to the principles of estimating the magnitude of the stresses on the different members of a structure, but not so in proportioning the members to resist those stresses.

The practical result is that a bridge which would be passed by the English Board of Trade would require to be strengthened 5 per cent. in some parts and 60 per cent. in others before it would be accepted by the German Government or by any of the leading railway companies in America. This undesirable state of affairs arises from the fact that in our own and some other countries many engineers still persistently ignore the fact that a bar of iron may be broken in two ways, namely, by the single application of a heavy stress or by the repeated application of a comparatively light stress. An athlete's muscles have often been likened to a bar of iron, but, if "fatigue" be in question, the simile is very wide of the truth. Intermittent action—the alternative pull and thrust of the rower, or of the laborer turning a winch—is what the muscle likes and the bar of iron abhors. Troopers dismount to rest their horses, but to relieve a bar of iron temporarily of load only serves to fatigue it. Half a century ago Braithwaite correctly attributed the failure of some girders, carrying a large brewery vat, to the vessel being sometimes full and sometimes empty, the repeated deflection, although imperceptibly slow and wholly free from vibration, deteriorating the metal, until, in the course of years, the girders broke. These girders were of cast iron; but it was equally well known that wrought iron was similarly affected, for in 1842 Nasmyth called the attention of this Section to the fact that the "alternate strain" in axles rendered them weak and brittle, and suggested annealing as a remedy, he having found that an axle which would snap with one blow when worn, would bear eighteen blows when new or after being annealed.

So important a matter as the action of intermittent stresses could not escape the attention of the Royal Commissioners appointed in 1849 to consider the application of iron to railway structures, and some significant and sufficiently conclusive experiments were made by Capt. Douglas Dalton and others. Cast-iron bars 3 inches square and 13 feet 6 inches span between the supports were deflected, both by the slow action of a cam and the percussive action of a swinging pendulum weight. When the deflection was that due to one-third of the breaking weight, about 50,000 successive bendings by the cam broke one of the bars, and about 1,000 blows from the pendulum another. When the deflection was increased from one-third to one-half, about 500 applications of the cam, and 100 blows, sufficed to rupture two of the specimens. Slow-moving weights on bars and on a small wrought-iron box girder gave analogous results; and the deduction drawn by the experimenters at the time was that "iron bars scarcely bear the reiterated application of one-third the breaking weight without injury, hence the prudence of always making beams capable of bearing six times the greatest weight that could be laid upon them."

Although these experiments were entirely confirmatory of all previous experience, they would appear to have little influenced the practice of engineers, since Fairbairn, more than ten years later, in a communication to this Section, said that opinions were still much divided upon the question whether the continuous change of load which many wrought-iron structures undergo has any permanent effect upon their ultimate powers of resistance. To assist in settling the question he communicated to the Association the results of some experiments carried out by himself and Prof. Unwin on a little riveted girder 20 feet span and 16 inches deep. Once more the same important but disregarded facts were enforced on the attention of engineers. About 5,000 applications of a load equal to four-tenths of the calculated breaking load fractured the beam with the small ultimate deflection of three-eighths of an inch, and subsequently, when repaired, the beam broke with one-third of the load and a deflection of but a quarter of an inch, which sufficiently indicated how small a margin the factor of safety of four, when currently adopted, allowed for defective manufacture, inferior material, and errors in calculation. Still nothing was done, and the general practice of engineers and the Board of Trade regulations continued unaltered.

Soon after the introduction of wrought-iron bridges on railways, the testimony of practical working was added to that of experiments. In 1848 several girder bridges of unduly light proportions were erected in America, and one of 66 foot span broke down under the action of the rolling load in the same manner as Fairbairn's little experimental girder. Again, in early American timber bridges the vertical tie-rods were often subject to stresses oscillating between 1 ton and 10 tons per square inch and upward. Many of these broke, as did also the suspension bolts in platforms subjected to similar stresses. In my own experience, dozens of broken flange-plates and angle-bars, and hundreds of sheared rivets, have been the silent witnesses of the destructive action of a live load. Like evidence was afforded by early constructed iron ships deficient in girder strength. Under the alternating stresses due to the action of the waves, weaknesses not at first apparent would in the course of time be developed, and additional strength, in the way of stringers and otherwise, became imperative.

If none of the preceding evidence had been forthcoming, the results of the historical series of experiments carried out by Wohler for the Prussian Ministry of Commerce would alone be conclusive. For the first time a truly scientific method of investigation was followed, and an attempt was made to determine the laws governing the already proved destructive action of intermittent stresses. In previous experiments the bar or girder was alternately fully loaded and wholly relieved of load. Wohler was not satisfied with this, but tested also the result of a partial relief of load. The striking fact was soon evidenced, on testing specimens under varying tensions, that the amount of the variation was as necessary to be considered as that of the maximum stress. Thus, an iron bar having a tensile strength of 24 tons per square inch broke with about 100,000 applications of a stress varying from *nil* to 21 tons, but resisted 4,000,000 applications of the 21 tons when the minimum stress was varied from *nil* to 11½ tons. The alternations of stress in the case of some test pieces numbered no less than 132,000,000; and too much credit cannot be bestowed by engineers upon Wohler for the ingenuity and patience which characterized his researches. As a result, it is proved beyond all further question that any bar or beam of cast iron, wrought iron, or steel may be fractured by the continued repetition of comparatively small stresses, and that, as the differences of stress increase, the maximum stress capable of being sustained diminishes.

Various formulæ based upon the preceding experiments have been proposed for the determination of the proper sectional area of the members of metallic structures. These formulæ differ in some essential respects, and doubtless many experiments are still required before any universally accepted rules can be laid down. Probably at the present time the engineers who have given the most attention to the subject are fairly in accord in holding that the admissible stress per square inch in a wrought-iron girder subject to a steady dead load would be one and a half times as great as that in a girder subject to a wholly live load, and three times that allowable in members subject to alternate tensile and compressive stresses of equal intensity, such as the piston rod of a steam engine or the central web-bracing of a lattice girder. If the alternations of stress to be guarded against are not assumably infinite in number, but only occasional—as in wind bracing for hurricane pressures, or in a vessel among exceptionally high waves—then the aforesaid ratio of 3, 2, and 1 would not apply, but would more nearly approach the ratios 6, 5, and 4.

Hundreds of existing railway bridges which carry twenty trains a day with perfect safety would break down quickly under twenty trains per hour. This fact was forced on my attention nearly twenty years ago by the fracture of a number of iron girders of ordinary strength under a five minute train service. Similarly, when in New York last year, I noticed, in the case of some hundreds of girders on the "Elevated Railway," that the alternate thrust and pull on the central diagonals from trains passing every two or three minutes had developed weaknesses which necessitated the bars being replaced by stronger ones after a very short service. Somewhat the same thing had to be done recently in this country with a bridge over the Trent, but the train service being small the life of the bars was measured by years instead of months. If ships were always among great waves, the number going to the bottom would be largely increased, for, according to Mr. John, late of Lloyd's, "many large merchant steamers afloat are so deficient in longitudinal strength that they are liable under certain conditions of sea to be strained in the upper works to a tension of from 8 to 9 tons per square inch, and to a compression of from 6 to 7 tons—stresses which the experiments already referred to proved would cause failure after a definite number of repetitions. Similarly, on taking ground, or being dry-docked with a heavy cargo on board, it has been shown that vessels are liable to stresses of over 11 tons per square inch on the reverse frames, but no permanent injury results from such high stresses, because the number of repetitions is necessarily very limited.

* Opening address by B. Baker, M.Inst.C.E., President of Section G, British Association, Aberdeen, 1885.

It appears natural enough to every one that a piece even of the toughest wire should be quickly broken if bent backward and forward to a sharp angle; but, perhaps, only to locomotive and marine engineers does it appear equally natural that the same result would follow in time if the bending were so small as to be quite imperceptible to the eye. A locomotive crank axle bends but 1-34 of an inch, and a straight driving axle the still smaller amount of 1-64 of an inch under the heaviest bending stresses to which they are subject, and yet their life is limited. During the year 1883 one iron axle in fifty broke in running, and one in fifteen was renewed in consequence of defects. Taking iron and steel axles together, the number then in use on the railways of the United Kingdom was 14,848, and of these, 911 required renewal during the year. Similarly, during the past three years no less than 228 ocean steamers were disabled by broken shafts, the average safe life of which is said to be about three or four years. In other words, experience has proved that a very moderate stress alternating from tension to compression, if repeated about one hundred million times, will cause fracture as surely as a sharp bending to an angle repeated perhaps only ten times.

I have myself made many experiments with a view to elucidate the laws affecting the strength of irons and steel works subject to frequent alternations of stress. Perhaps the most suggestive series was one in which I subjected flat steel bars about 3 feet long, in pairs, to repeated bendings until one bar broke, and then testing the surviving bar under direct tensile and compressive stresses, to ascertain to what extent the metal had deteriorated. It had come under my notice, as a practical engineer, that if the compression members of a structure were unduly weak, the fact became quickly evident, perhaps under the test load; but if, on the other hand, the tension members were weak, no evidence might appear of the fact until frequent repetition of stresses during several years had caused them to fracture without any measurable elongation of the metal. In the case of crank-shafts, also, the fracture is invariably due to a tearing and not a crushing action. It appeared to me, therefore, eminently probable that repetition of stresses might be far more prejudicial to tension than to compression members, and, if so, the fact ought to be taken account of in proportioning a structure.

This proved to be the case in my experiments. For example, the companion bars to those which had broken with 18,000 reversals of a stress less than half the original breaking weight behaved, when tested as columns thirty diameters in length, precisely the same as similar bars which had done no work at all, whereas when tested in tension the elongation was reduced from the original 25 per cent. to 2·5 per cent., and the fracture appeared to indicate that the bars had been made of three different kinds of steel imperfectly welded together. With a stress reduced by one-fourth, the number of bendings required to break the bar was increased to 1,200,000. In this instance the calculated maximum working stress on the extreme fibers was 43 per cent. of the direct ultimate tensile resistance of the steel, and about 30 per cent. of the stress the bar was capable of sustaining as a beam under the single application of a load. Of course, the bars failed by tension, and the extreme fibers had thus deteriorated as regards tensile stresses to the extent indicated by the above percentages. Tested as a column, however, the injury the bar had received from the 1,200,000 bendings was inappreciable. The ductility was of course very largely reduced, but ductility is a quality of comparatively little importance when a material is in compression. There is no ductility in the slender Gothic stone columns of our cathedrals, which, though heavily stressed, have carried their loads for centuries. As I found repeated bendings raised the limit of elasticity, I rather anticipated finding an increased resistance from this cause in long columns. This did not prove to be the case, nor did I find any difference in short columns four diameters in length.

In addition to the preceding experiments with rectangular bars, I have tested the endurance of many revolving shafts of cast iron, wrought iron, and steel, with similar results. About 5,000 reversals of a stress equal to one-half the static breaking weight sufficed generally to cause the snapping of a shaft of any of the above materials. When the stress was reduced and the number of applications increased, I found the relative endurance of solid beams to be more nearly proportional to the tensile strength of the metal than to the breaking weight of the beam, a distinction of great importance where axles, springs, and similar things are concerned. Many of my experiments were singularly suggestive. Thus, it was instructive to see a bar of cast iron loaded with a weight which, according to Fairbairn's experiments, it should have carried for a long series of years, broken in two minutes when set gently rotating. Also to find a bar of the finest mild steel so changed in constitution by some months of rotation as to offer no advantages either in strength or toughness over a new cast iron bar of the same section.

Although, as already stated, many more experiments are required before universally acceptable rules can be laid down, I have thoroughly convinced myself that where stresses of varying intensity occur, tension and compression members should be treated on an entirely different basis. If, in the case of a tension member, the sectional area be increased 50 per cent., because the stress instead of being constant ranges from *nil* to the maximum, then I think 20 per cent. increase would be a liberal allowance in the case of a compression member. I have also satisfied myself that if a metallic railway bridge is to be built at a minimum first cost, and be free from all future charges for structural maintenance, it is essential to vary the working stress upon the metal within very wide limits, regard being had not merely to the effect of intermittent stresses, but also to the relative limits of elasticity in tension and compression members even under a steady load.

Why an originally strong and ductile metal should become weak and brittle under the frequent repetition of a moderate stress has not yet been explained. Lord Bacon touched upon the subject two or three centuries ago, but you may consider his explanation not wholly satisfactory. He said: "Of bodies, some are fragile, and some are tough and not fragile. Of fragility, the cause is an impotency to be extended, and the cause of this inaptness is the small quantity of spirits." I am sorry to have no better explanation to offer, but whatever may be the immediate cause of fragility, no doubt exists that it is induced in metals by frequent bendings, such as a railway bridge undergoes. This fact, however, is not recognized in our Board of Trade Regulations, which remain as they were in the dark ages, as do those of the Ministry of Public Works of France and other countries. With us it is simply provided that the stress on an iron bridge must not exceed 5 tons per square inch on the effective section of the metal. In France it is still worse, as the limiting stress of rather under 4 tons per square inch is estimated upon the gross section, regardless of the extent to which the plates may be perforated by rivet holes. In neither case is any regard had in the rules to intermittent stresses or the flexure of compression members. In Austria the regulations make a small provision for these elements; and American specifications make a large one, the limiting stresses, instead of being constant at 5 tons, as with us, ranging from about 2½ tons to 6¾ tons per square inch, according to circumstances. It is hardly necessary that I should say more to justify my statement that, as regards the admissible intensity of stress on metallic bridges, absolute chaos prevails.

Engineers must remember that if satisfactory rules are to be framed, they, and not governmental departments, must take the initiative In former days the British Association did much to direct the attention of engineers to this important matter, but, so far as I know, the subject has been dropped for the past twenty years, and I have ventured, therefore, to bring it before you again in some detail. We are here avowedly for the advancement of science, and I have not been deterred by the dryness of the subject from soliciting your attention to a branch of science which is sadly in need of advancement.

Had I been addressing a less scientific audience, I might have been tempted rather to boast of the achievements of engineers than to point out their shortcomings. The progress in many branches of mechanical science during the past fifty years has exceeded the anticipation of the most far-seeing. Fifty years ago the chairman of the Stockton and Darlington Railway, when asked by a Parliamentary committee if he thought any further improvements would be possible on railways, replied that he understood in future all new railways would have a high earth-work bank on each side to prevent engines toppling over the embankments, and to arrest hot ashes, which continually set fire to neighboring stacks, but in other respects he appeared to think perfection was attained. Shortly before the introduction of locomotives, it was also thought perfection was attained when low trucks were attached to the trains to carry the horses over the portions of the line where descending grades prevailed, and all the newspapers announced, with a great flourish of trumpets, that a year's experience showed the saving in horseflesh to be fully 33 per cent.

Although these views seem childlike enough from our present standpoint, I have no doubt that as able and enterprising engineers existed prior to the age of steam and steel as exist now, and their work was as beneficial to mankind, though different in direction. In the important matter of water supply to towns, indeed, I doubt whether, having reference to facility of execution, even greater works were not done 2,000 years ago than now. Herodotus speaks of a tunnel 8 feet square, and nearly a mile long, driven through a mountain in order to supply the city of Samos with water; and his statement, though long doubted, was verified in 1882 through the abbot of a neighboring cloister accidentally unearthing some stone slabs. The German Archæological Society sent out Ernst Fabricius to make a complete survey of the work, and the record reads like that of a modern engineering undertaking. Thus, from a covered reservoir in the hills proceeded an arched conduit about 1,000 yards long, partly driven as a tunnel and partly executed on the "cut and cover" system adopted on the London underground railway. The tunnel proper, more than 1,100 yards in length, was hewn by hammer and chisel through the solid limestone rock. It was driven from the two ends like the great Alpine tunnels, without intermediate shafts, and the engineers of 2,400 years ago might well be congratulated for getting only some dozen feet out of level and little more out of line. From the lower end of the tunnel branches were constructed to supply the city mains and fountains, and the explorers found ventilating shafts and side entrances, earthenware socket-pipes with cement joints, and other interesting details connected with the water supply of towns.

In the matter of masonry bridges, also, as great works were undertaken some centuries ago as in recent times. Sir John Rennie stated, in his presidential address at the Institute of Civil Engineers, that the bridge across the Dee at Chester was the "largest stone arch on record." That is not so. The Dee bridge consists of a single segmental arch 200 feet span and 42 feet rise; but across the Adda, in Northern Italy, was built, in the year 1377—more than 500 years ago—a similar segmental arch bridge of no less than 237 feet span and 68 feet rise. Ferario not long since published an account of this, for the period, colossal work, from which it would appear that its life was but thirty-nine years, the bridge having been destroyed for military reasons on December 21, 1416. I believe our American cousins claim to have built the biggest existing stone arch bridge in the world—that across the Cabin Johns Creek; but the span, after all, is only 215 feet, or 10 per cent. smaller than the 500-year-old bridge. In timber bridges, doubtless the Americans will ever head the list, for the bridge of 340 feet span built across the Schuylkill three-quarters of a century ago will probably never be surpassed. Our ancestors were splendid workers in stone and timber, and, if they had been in possession of an unlimited supply of iron and steel, I fear there would have been little left for modern bridge-builders to originate.

The labors of the present generation of engineers are lightened beyond all estimate by labor-saving appliances. To prove how much the world is indebted to students of this branch of mechanical science, and how rapid is the development of a really good mechanical notion, it is only necessary to refer to the numerous hydraulic appliances of the kind first introduced forty years ago by a distinguished past-President, Sir W. G. Armstrong. Addressing you in 1854, Sir William Armstrong explained that the object he had in view from the first was "to provide, in substitution of manual labor, a method of working a multiplicity of machines, intermittent in their action and extending over a large area, by means of transmitted power, produced by a steam engine and accumulated at one central point." The number of cases in which this method of working is a desideratum, or even indispensable, would appear to be limitless. I should be sorry, indeed, to have anything to do with building the Forth bridge if hydraulic appliances were not at hand to do a giant's work. Let me shortly describe to you what we are doing there at the present time. More than 42,000 tons of steel plates and bars have to be bent, planed, drilled, and riveted together before or after erection, and hydraulic appliances are used throughout. The plates are handled in the shops by numerous little hydraulic cranes of special design, without any complication of multiplying sheaves, the whole arm being raised with the load by a 4 inch direct-acting ram of 6 feet stroke. A total length of no less than 60 miles of steel plates, ranging in thickness from 1¼ in. to ⅜ inch, have to be bent to radii of from 6 feet to 9 inches, which is done in heavy cast-iron dies squeezed together by four rams of 24 inches in diameter, and the same stroke. With the ordinary working pressure of 1,000 lb. per square inch, the power of the press is thus about 1,750 tons. Some 3,000 pieces, shaped like the lid of a box, 15 inches by 12 inches wide, with a 3 inch deep rim all around, were required to be made of ½ inch steel plate, and this was easily effected in two heats by a couple of strokes of a 14 inch ram. In numberless other instances steady hydraulic pressure has been substituted by Mr. Arrol, our able contractor, for the usual cutting and welding under the blacksmith's hammer.

Hydraulic appliances are also an indispensable part of the scheme for erecting the great 1,700 foot spans. Massive girders will be put together at a low level, and be hoisted as high as the top of St. Paul' Cathedral by hydraulic power. Continuous girders, nearly a third of a mile in length, will be similarly raised. Not only the girders, but workmen, their sheds, cranes, and appliances, will be carried up steadily and imperceptibly as the work of erection proceeds, on platforms weighing in some instances more than 1,000 tons. It is hardly necessary to say that every rivet in the bridge will be closed up by hydraulic power, the machines being in many instances of novel design, specially adapted to the work. Thus the bed-plates, which in ordinary bridges are simple castings, in the Forth bridge are necessarily built up of numerous steel plates, the size of each bed-plate being 37 feet long by 17 feet 6 inches wide. To grip together the 47 separate plates into a solid mass, 3,800 rivets 1¼ inches in diameter with countersunk heads on both sides are required, and, remembering that the least dimension of the bed-plate is 17 feet 6 inches, it will be seen that the ordinary "gap" riveter would not be applicable. A special machine was therefore designed by Mr. Arrol, consisting of a pair of girders and a pair of rams, between which the bed-plate to be riveted together lies. A double ram machine had for like reasons to be devised for riveting up the great tubular struts of the bridge.

Not merely in the superstructure, but in the construction of the foundations, were hydraulic appliances of a novel character indispensable at the Forth bridge. Huge wrought-iron caissons or cylinders, 70 feet diameter and 72 feet high, were taken up and set down as readily as a man would handle a bucket. In sinking these caissons through the mud and clay of the Forth, compressed air was used. When the bowlder-clay was reached, the labor of excavating the extremely hard and tenacious material in the compressed-air chamber proved too exhausting, pick-axes were of little avail, and the Italian laborers who were chiefly employed lost heart over the job altogether. But a giant power was at hand, and only required tools fit for the work. Spades with hydraulic rams in the hollow handles were made, and, with the roof of the compressed-air chamber to thrust against, the workmen had merely to hold the handle vertically, turn a little tap, and down went the spade with a force of three tons into the hitherto impracticable clay as sweetly as a knife into butter. Probably, when addressing you thirty years ago, Sir William Armstrong never anticipated that a number of hydraulic spades would be digging away in an electrically lighted chamber or diving-bell, 70 feet diameter and 7 feet high, 90 feet below the waves of the sea; but still the spades come strictly within the definition of the class of machines, intermittent in their action and extending over a large area, which it was his aim to introduce. It would be possible, indeed, with the appliances at the Forth bridge, to arrange that the simple opening of a valve should start digging at the bottom of the sea, riveting at a height of nearly 400 feet above the sea, and all the multifarious operations of bending, forging, and hoisting, extending over a site a mile and a half in length.

It would not only be impossible to build a Forth bridge, but it would be equally impossible to fight a modern ironclad, without the aid of hydraulic appliances. Most of the Presidents of this Section have referred in the course of their addresses to our navy, and certainly the subject is a tempting one, for the progress of mechanical science in recent years could not be better illustrated than by a description of the innumerable appliances which go to the making and working of a modern ironclad. Let me quote a single passage from a pamphlet by a naval officer, which caused a great stir a few years before the Crimean war, that I may recall to your minds what was the speed and what the armament of our fleet at that comparatively recent period. "Conceive," said Capt. Plunkett, R.N., "a British and French fleet issuing simultaneously from Spithead and Cherbourg; seven hours' steaming at the rate of six miles an hour will bring them together. A single glance at the heavy and well-appointed tiers of a line-of-battle ship's guns will satisfy any one that they are no toys to be placed in the hands of novices. Formidable batteries of the heaviest ordnance are there—not a gun under a 32-pounder, and many 68-pounder shell guns." In little more than a quarter of a century engineers have changed all that, and advanced to 20-knot vessels and 120-ton guns. Archæologists tell us that our predecessors in mechanical science of the Stone Age were apparently a thousand or more years in finding out that the best way of fitting an ax was to slip the handle through the ax, and not the ax through the handle. Engineers of the present day may be excused, therefore, for occasionally illustrating the rapidity of the advance of their science by contrasting the ships of thirty years ago with our modern ironclads.

The latest type of battle ship weighs, fully equipped,

about 10,000 tons. There are about 3,400 tons of steel in her hull, apart from armor, which, with its backing, will weigh a further 2,800 tons. The machinery, largely of steel, is about 1,400 tons; the armament, including ammunition, 1,100 tons; the coals, 1,100 tons; and general equipment, 270 tons. A detailed description bristles with the word "steel," and enthusiastic newspaper reporters sent down to Chatham Dockyard can no more "spin out their copy" which Cowper's oft-quoted lines on the "launch of a first-rate":

"Giant oaks of bold expansion.
O'er seven hundred acres fell,
All to build thy noble mansion,
Where our hearts of oak do dwell."

A latter day poet might boast of 700 acres being exhausted by a single vessel, but it would be a coal-field and not a forest. Accepting Prof. Phillips' estimate of the average rate of formation of coal, it may be shown that a hard-worked American liner during her lifetime burns as much coal as would be produced on the area of 700 acres in a period of 2,000 years. We are thus with our steel ships using up our primeval forests at a far more extravagant rate than that at which our immediate forefathers cleared the oak forests. Coal is the great stimulant of the modern engineer. Pope Pius the Second has left on record an expression of the astonishment he felt when visiting Scotland, in the fifteenth century, on seeing poor people in rags begging at church doors, and receiving for alms pieces of black stone, with which they went away contented. To such early familiarity with coal may, however, be due the fact that Scotland has ever led the way in the development of the steam engine, and that at the date of the battle of Waterloo she had built and registered seven steam vessels, while England could boast of none.

Probably none but a poet or a painter would wish for a return to our old oak sailing ships. Some few people still entertain the illusion that the picturesque old tubs were better sea boats than our razor-ended steamers; but, speaking of them in 1846, Admiral Napier said: "The ships look very charming in harbor, but to judge of them properly you should see them in a gale of wind, when it would be found they would roll 45° leeward and 43° windward." Even our first ironclads were not so bad as that, for although, according to the *Times*, when the squadron was on trial in the Bay of Biscay, the ships rocked wildly to the rising swell and the sea broke in great hills of surf, yet the maximum roll signaled by the worst roller of the lot, the Lord Warden, was but 35° leeward and 27° windward—a total range of 62° as compared with 88° in the old line of battle ships.

We have heard much about the state of the navy during the past twelve months. A dip into the publications of the British Association—which in this, as in other respects, afford a fair indication of what is uppermost in people's minds—will show that similar discussions have recurred periodically, at any rate since 1830. If we consult Hansard, as I had occasion to do recently, we find the same remark applies to periods long antecedent to 1830.

It amounts almost to a religious conviction in the mind of a Briton that Providence will not be on his side unless his fleet is at least equal to that of France and Russia united. What would be said now of a Minister who met an attack on the administration of the navy by demonstrating that we had *half* as many line of battle ships as Russia; and yet that was literally done less than fifty years ago. Speaking in the House of Commons on March 4, 1839, the Secretary of the Admiralty said: "For the last six months unceasing attacks have been made upon our naval administration, describing our navy as in a state of the utmost decrepitude, and Tory papers say that shameful reductions have been made in the navy by the present Government. It will be a consolation to my honorable friends to be assured that we have for years lived unharmed through dangers as great as that to which we are now exposed. In 1817 we had fifteen sail of the line in commission, and Russia had 30; in 1823 we had 12, and Russia 37; in 1832 we had 11, and Russia 36; and now we have 20, and the Russians 43, having raised our ships to nearly half the number of those of Russia.

Now as to our guns. The past twelve months is by no means the first occasion on which the armament of our navy has been attacked. Three years subsequent to the speech of the Secretary of the Admiralty just referred to, Sir Charles Napier made a statement from his place in Parliament of so extraordinary a character that I make no apology for quoting his exact words, as a reminder of the past and a warning for the future: "At the end of the last war, the guns were in such a bad state that, when fired, they would scarcely hit an enemy, and during the latter period of the American war a secret order was issued that British ships of war should not engage American frigates, because the former were in such an inefficient state." As for himself, said the plain-spoken old admiral, when he got the order he put it in "the only place fit to receive it, the quarter-galley."

Happily, from our insular position, the change which the progress of mechanical science has wrought in military operations has not been brought home to the people of this country in the same vivid manner that it has to the people of the continents of Europe and America. In the American war, the Franco-German war, and the Russo-Turkish war, the construction and equipment of railway works by engineers was an essential part of all great movements. The Russians, in 1877, constructed a railway from Bender to Galatz, 180 miles in length, in fifty-eight working days, or at the rate of more than three miles per day. Altogether, in the three latter months of that year they laid out and built about 240 miles of railway, and purchased and stocked the line with 110 locomotives and 2,200 wagons. They also built numerous trestle bridges, together with an opening bridge and a ferry across the Danube.

We have had recent experience of the slowness of primitive modes of transport in the tedious advance of Lord Wolseley's handful of men in whale-boats up the Nile. It was the intention of the late Khedive, partly from military and partly from commercial considerations, to construct a railway exactly on the line of advance subsequently followed by Wolseley. My partner, Mr. Fowler, had the railway sent out in 1873, and the works were shortly after commenced. The total length was 550 miles, and the estimated cost, including rolling-stock and repairing-shops, 4,000,000*l*. Owing to financial difficulties the works were abandoned, but the 64 miles constructed by Mr. Fowler, and the recent extensions of the same by the military, proved of great service to the expedition, even some of the steam-launches being taken by railway to save delays at the cataracts.

During the siege of Paris, the German forces were dependent upon supplies drawn from their base, and the army requirements were fully met by one line of railway running from twelve to fourteen trains per day. Military authorities state that a train load of about 250 tons is equal to two days' rations and corn for an army corps of 37,000 men and 10,000 horses. The military operations in Egypt have proved that, even in the heart of Africa, railways, steamboats, electric lights, machine guns, and other offspring of mechanical science are essential ingredients of success.

Members of this Section who visited the United States last year not for the first time could hardly have failed to notice that American and European engineering practice are gradually presenting fewer points of difference. Early American iron railway bridges were little more than the ordinary type of timber bridge done into iron, and the characteristic features, therefore, were great depth of truss, forged links, pins, screw bolts, round or rectangular struts, cast-iron junction pieces, and, in brief, an assemblage of a number of independent members more or less securely bolted together, and not, as in European bridges, a solidly riveted mass of plates and angle-bars. At the present moment the typical American bridge is distinctly derived from the grafting of German practice on the original parent stock. Pin connections are still generally used in bridges of any size, but the top members and connections are more European than American in construction, while for girders of moderate span, such as those on the many miles of elevated railway in New York, riveted girders of purely European type are admittedly the cheapest and most durable. From my conversations with leading American bridge builders, I am satisfied that their future practice and our own will approach still more nearly.

We should never think of building another Victoria tubular bridge across the St. Lawrence, or repeat the design of the fallen Tay bridge, nor would they again imitate in iron an old timber bridge, or repeat the design of the fallen Ashtabula bridge. In one respect the practice in America tends to the production of better and cheaper bridges than does our own practice, and it is this: each of the great bridge-building firms adopts by preference a particular type design, and the works are laid out to produce bridges of this kind. It is an old adage that practice makes perfect, and by adhering to one type, and not vaguely wandering over the whole field of design, details are perfected and a really good bridge is the result. Engineers in America therefore need only specify the span of their bridge, and the rolling load to be provided for, with certain limiting stresses, and they can make sure of obtaining a number of tenders from different makers of bridges, varying somewhat in design, but complying with all the requirements. With us, on the other hand, it is too often the privilege of a pupil to try his 'prentice hand on the design for a bridge, and it is no wonder, therefore, that many curious bits of detail meet the eye of an observant foreigner inspecting our railways.

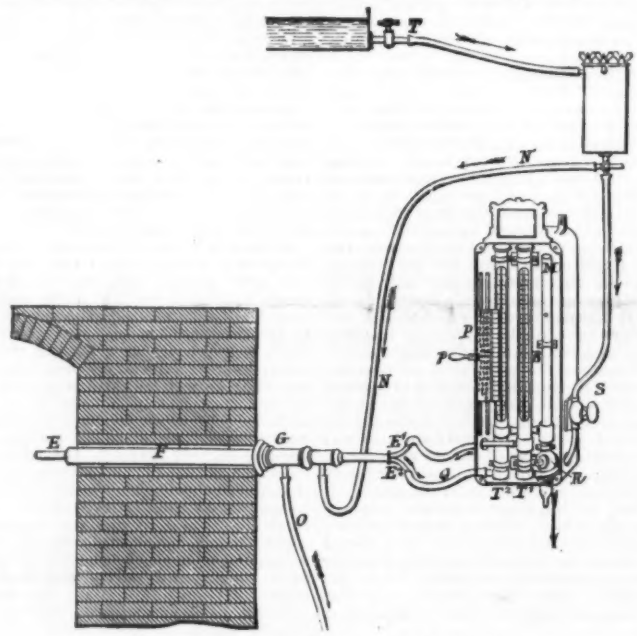
The magnificent steel wire rope suspension bridge of 1,600 feet span built by Roebling across the East River at New York well marks the advanced state of mechanical science in America as regards bridge building. It is worthy of note that, at the second meeting of the British Association, held so long back as 1832, there was a paper on suspension bridges, and the author entreated the attention of the scientific world, and particularly of civil engineers, to the serious consideration of the question: "How far ought iron to be hereafter used for suspension bridges, since a steel bridge of equal strength and superior durability could be built at much less cost?" "I earnestly call upon the iron-masters of the United Kingdom," said he, "to lose no time in endeavoring to solve this question." In this, as in many other engineering matters, America has given us a lead. America is, indeed, a paradise for mechanics. When the British Association was inaugurated, years ago, there was, I believe, no intention to have a section for the discussion of mechanical science. Possibly it may have been considered too mean a branch. Even the usually generous Shakespeare speaks contemptuously of "mechanic slaves, with greasy aprons, rules, and hammers;" and our old friend Dr. Johnson's definition of "mechanical" is "mean, servile." We have lived down this feeling of contempt, and the world admits that the "greasy apron" is as honorable a badge as the priest's cassock or the warrior's coat of mail, and has played as important a part in the great work of civilizing humanity and turning bloodthirsty savages into law-abiding citizens.

As I have had occasion to refer to Canada and America in the course of my remarks, I cannot refrain from expressing the high appreciation which I am sure every member of this Section entertains of the cordiality and warmth of our reception on the other side of the Atlantic last year. Such incidents make us forget that differences have ever existed between the two countries. I was amused the other day, on reading in Dr. Doran's "Annals of the Stage," that, in the year 1777, the theatrical company from Edinburgh was captured on its voyage to Aberdeen by an American privateer, and taken off Heaven knows where, for it did not turn up again. This, you will say, was a long time ago; but, if you glance through the speeches of our present gracious sovereign, you will find one in which Her Majesty speaks with "deep concern" of insurrection in Lower Canada, and of hostile incursions into Upper Canada by certain "lawless inhabitants" of the United States of North America.

This is strange reading, after our last year's experience. Gentlemen, I may not have carried you with me in some things I have said, but I think you will all agree with me in this: that the statesman who should suffer any slight difference of opinion to develop into a serious breach between ourselves and our brethren in Canada and cousins in America would, to quote the words of Burke, "far from being qualified to be directors of the great movements of this empire, be not fit even to turn a wheel in the machine."

THE SAINTIGNON PYROMETER.

IN the pyrometer invented by M. De Saintignon, high temperatures are measured by inserting in the furnace a tube through which a current of water is



SAINTIGNON'S PYROMETER.

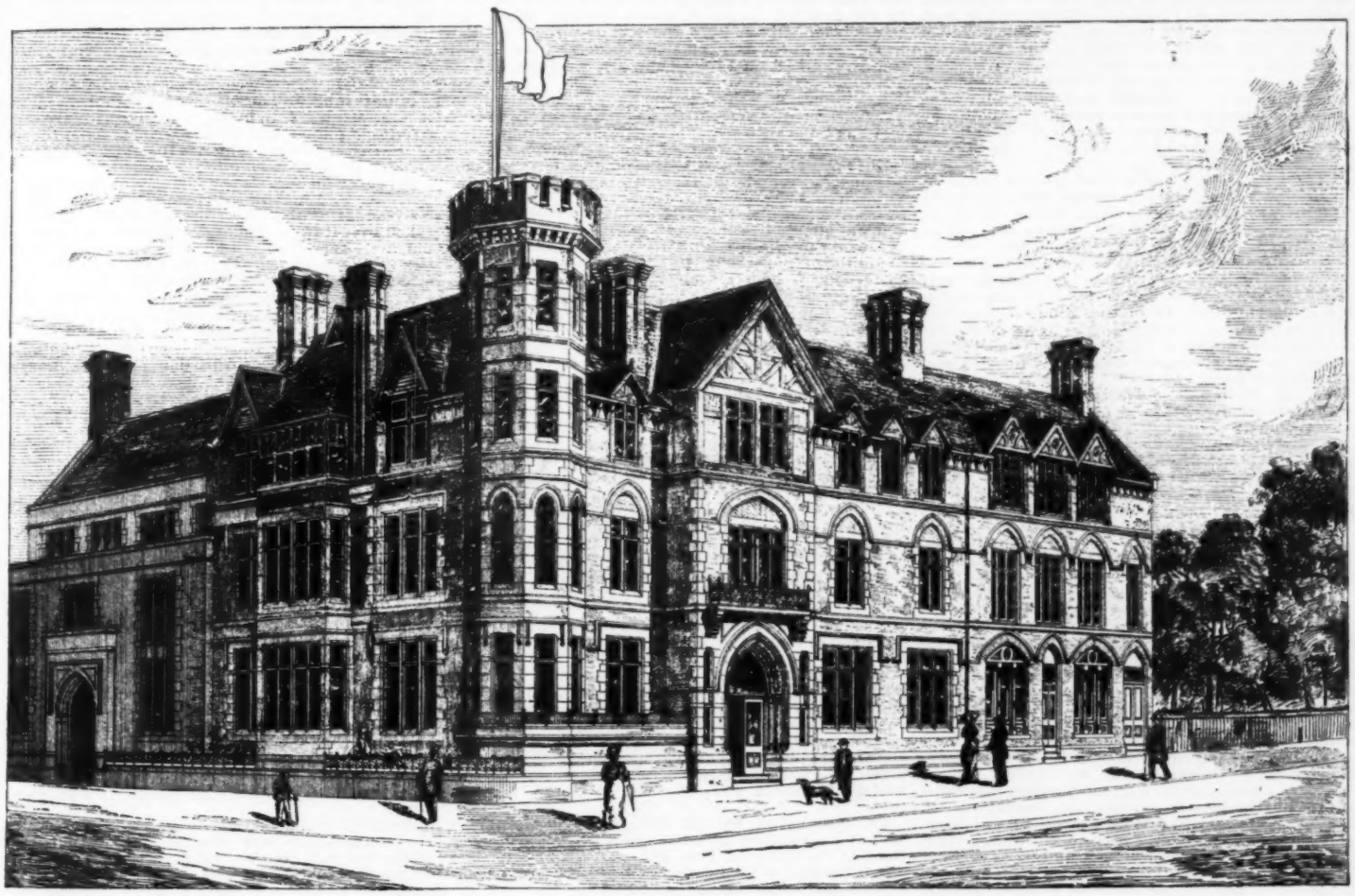
passing at a uniform rate. The temperature of the water is measured by a mercurial thermometer as it enters the tube, and again as it leaves, and from the difference of the two readings the intensity to which it has been exposed is deduced. The instrument is made in two forms. In the first, it is applicable to heated spaces with thin walls, such as smoke boxes; and in the second, to furnaces inclosed with masonry. It is the latter form of which we annex an illustration. It comprises two thermometers, T^1, T^2, graduated with long scales, and connected by elastic tubes to the pipe, E, which is passed through the wall into the furnace the temperature of which it is desired to measure. A uniform current of water flows from a reservoir situated at a height of about ten feet above the pyrometer, passes through a filter, and descends into a vessel encircling the bulb of the thermometer, T^1. This thermometer indicates the initial temperature of the water. From it the water flows by the elastic tube, E^1, into the copper tube, E, which is situated within the furnace, and is exposed to its heat at the particular point where it is stationed for the time being. The water becomes heated in its passage, and returns to the second thermometer, E^2, where its temperature is again measured. The speed of the current, and the length of the tube exposed to the action of the fire, are so adjusted that the water is raised one degree for each twenty-five degrees of the furnace. A plate, P, furnished with a handle, *p*, carries a scale advancing twenty-five degrees for each degree of the thermometer scale; its zero point is placed opposite the head of the column of mercury in the thermometer, T^1, and the temperature is read opposite the top of the mercury in T^2. After leaving the second thermometer, the water enters the pressure gauge, M, which consists of a tube open at its upper extremity, and carrying at its lower end a cock, R, by which the water escapes. By adjusting the cock, S, the flow is regulated until the water rises to the mark, B, in the tube; and so long as it does not vary from this point, it is known that the calculated discharge is taking place through the cock, R.

It is necessary, for correct determinations, that the water should not gather heat until it actually enters the furnace, and to this end the tube, E, is covered with a refrigerating envelope, F, which incloses and

protects all of it, except the part in the furnace. This envelope consists of a double copper pipe, to the center of which there pass two small pipes, E^1, E^2. A current of water, quite independent of that which flows in the pyrometer, enters the envelope by the pipe, N, passes along its entire length, and escapes by the tube, O. The two tubes carrying the water used in the pyrometer are surrounded by a non-conducting covering; and in order that the refrigerating envelope may not have any influence on the pyrometer tubes, it is arranged that the water leaving it shall be at a mean temperature between the initial and terminal temperatures of the water in the tube, E. The pyrometer has been applied with much success to blast furnaces, glass works, porcelain and earthenware kilns, gas works, bake houses, and to many other apparatus requiring high temperatures. It is shown at the Inventions Exhibition, in Group II., at the stand of M. Brin, who exhibits a method of making oxygen, in the North Court of the South Gallery.—*Engineering.*

BOWLING GREEN HOTEL, KENILWORTH.

THIS property having recently changed hands, the present owner has commenced to replace the existing old-fashioned building with a large hotel, which he intends to be suitable for the accommodation of the numerous visitors to Kenilworth from all parts of the world. The walls of the building will be of red brick, with Bath stone dressings, and the gables will be half-timbered, as shown in the drawing. The internal accommodation comprises two large coffee rooms, public and private bar, bar parlor, billiard room, smoking room, club room about 30 ft. by 20 ft., large entrance hall and staircase, two large sitting rooms on the first floor commanding a fine view, and 18 bedrooms, besides the usual kitchen accommodation, etc. The heights of the various floors, measured in the clear, are as follows: ground floor, 12 ft.; first floor, 11 ft.; and the second floor, 10 ft. The tower at the junction of the Rosemary hill and the Abbey road is 55 ft. in height from the ground to the top of the parapet, and a splendid and uninterrupted view of the ruins of Kenilworth Castle and the surrounding country will be seen from the top. Some curious deeds in the possession of the proprietor show the license of the property to be the oldest in Kenilworth. The architect is Mr. James P. Norrington, Birmingham; and the proprietor of the hotel, Mr. T. B. Cooper, Kenilworth.



BOWLING GREEN HOTEL, KENILWORTH.

WHAT CIVILIZATION OWES THE ARCHITECT AND CIVIL ENGINEER.*

By GEORGE R. BRAMHALL.

OF all the skilled professions, it is safe to assert that those of the architect and civil engineer stand in the front rank among civilized nations; not only for the wealth, convenience, and comfort they have contributed to society, but as the representatives of the grandest conceptions, the boldest achievements, that have been bequeathed either the Old or the New World.

And these achievements are of a character well calculated to excite in the mind of every intelligent being the highest degree of wonder and amazement.

While statesmen and jurists have framed wise and humane laws; the military defended them, maintained right, and put down rebellion; astronomers and mathematicians measured planets, given the movements of worlds and laws of navigation; theologians instructed in religion; musicians, poets, and painters entertained and delighted multitudes by their powers of melody, pictures, and song; physicians showed the laws of health and aided longevity; chemists explained the laws of combination and reaction, the mode of composition, and process of decay; none have left such stupendous and striking demonstrations of wealth, genius, and grandeur as the architect and the civil engineer.

Denon, the great French traveler and architect, well says, in speaking of the ancient Assyrian and Egyptian architecture, that it appears like a dream or the work of giants; and he fancied he saw on every stone the words "posterity and eternity." Should a peasant, he says, be drawn out from his mud cottage and placed before such edifices, would he not believe there existed a wide difference between himself and beings able to construct them? And, without any idea of architecture, would he not say, "This is the work of a god; a man would not dare to do it, nor inhabit it"?

War and defense, coupled with that quality of man's nature which constitutes the principle of sociality and love of home, that has been implanted in the heart of every race and type of the animal man, and is found to exist even in the lower animals and insects, indicate the primal necessity for the architect and engineer.

Man's love for his offspring, family, and social relations called for shelter, and as he grew in intelligence the necessity forced itself upon his mind of providing a permanent place of abode and protection, not only against the inclemencies of the seasons, but also against his own race and his more natural enemies, wild beasts.

If man is the resultant of the forces of nature, by a long process of evolution (which is highly improbable), he had his first instruction in the art of building from the bee, ant, beaver, otter, musk-rat, and other animals.

This is not an unreasonable or unnatural conclusion, since he is first found dwelling in caves, hollow trees, tents, and mud huts, which show no greater evidences of skill in their construction and arrangement for protection, comfort, and convenience than those of the animals.

But *these* builders have made no progress in their mode of life, and we are forced to leave them in the same habitations they were found in five thousand years ago.

There seems to be conclusive evidence that man, although none the less an animal, was endowed by the Creator, at the beginning, with all the powers and faculties of reasoning we find him possessing to-day.

He has been traced, step by step, from the cave, tent, mud hut, log hut, and house of hewn logs, to the temples, churches, and cathedrals which adorn Europe and Asia, and the magnificent public buildings, legislative halls, palatial mansions, beautiful villas, and elegant homes of a free people, scattered all over these United States of North America, our own cherished land of progress.

The magnitude of the subject permits only a cursory view of the most notable ancient and modern achievements.

Those in the Old World commanding the greatest attention are the temples, cathedrals, churches, and aqueducts, and the reclamation of the Netherlands, better known as Holland.

There appears to have been a long period after the animal man emerged from his caves, huts of mud, and dwellings on piles (of which evidences are found in the lakes of Switzerland) before he is found in villages and cities, and very little is known of his progress in architecture.

The first account, after this long lapse of time, seems to be of the building of the Tower of Babel, in which, it is claimed, that miraculous event, the confusion of tongues, occurred; and the fabulous mention of the city of Babylon.

Some Eastern writers give the height of the Tower as twelve miles, while St. Jerome more moderately asserts it was only four. The geographer Strabo, who may be relied on, says it was six hundred and fifty feet, which is more in accordance with our modern ideas and reason.

It is supposed that the city of Babylon and the Temple of Belus afterward occupied this same site. For a long period the whole history of this marvelous city is enshrouded in such a cloud of mysticism that it is exceedingly difficult for travelers or writers to determine anything reliable concerning it. It was founded 2,000 years B. C., and rebuilt 1,200 before the Christian era.

Nineveh, the splendid capital of the Assyrian empire, was sixty miles in circuit, and surrounded by high walls.

The accounts of the few travelers who long ago visited Asia and Africa were ridiculed and treated as extravagant fictions; but during the last century, and especially since the commencement of the present, the investigations of scientific men have verified these seemingly incredible narratives. Stupendous edifices remain to demonstrate the truth of these wonderful stories, while structures of surpassing magnificence astonish the traveler in Egypt, Hindostan, and Persia. When or by whom these everlasting monuments of man's might were erected, the present inhabitants know not. Their antiquity dates back to a period shrouded in dark uncertainty, upon which authentic history throws no light. They are themselves the only, the mysterious, the indestructible records.

It is impossible to determine with certainty which of these three countries first brought architecture to the degree of excellence which these remains exhibit. Sir William Jones and other Orientalists contend for the superior antiquity of Hindostan, and assert that the East was not only the birthplace of art and science, but that they were there nurtured till they grew to manhood. While this may be true, there is also strong testimony on the side of Egypt. Here, it is supposed by some antiquaries, inventive genius in architecture arose, and thence spread through the civilized regions of the earth. Others trace it farther down the Nile, and consider Ethiopia the land from which light emanated.

The traveler in Egypt is filled with wonder and admiration at the number, size, and magnificence of the structures still standing upon the banks of the mysterious Nile. They are of three distinct orders: pyramids, excavations, and temples.

The famous pyramids, forty or more in number, of different sizes and of various materials, are scattered over a plain extending from Cairo about fifty miles along the Nile. Cheops, said to be five hundred feet high, is the largest structure in the world, or, in other words, the greatest mass of materials men have ever placed together to form a single building. A distinguished countryman says, "The oldest pyramid is yet the most perfect work of art, though it has stood more than three thousand years."

The temples, scattered in rich profusion on both sides of the Nile as far as the cataracts, are so numerous and interesting that it is exceedingly difficult to

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know which to select for description. The splendid work prepared by the savants who accompanied Napoleon's expedition gives a perfect representation of these wonderful remains of Egyptian architecture.

Hundred-gated Thebes, spreading her solemn ruins on both sides of the river, shows the oldest specimens of true Egyptian art. Professor Heeren attempts to prove that Luxor, one of these old edifices, was a palace or building for civil purposes, though the general plan resembles a temple. He gives, among other circumstances, evidence to the effect that the occupations and scenes of daily life are depicted upon the walls of some apartments.

Among these mighty ruins must be mentioned the obelisks or monoliths. The sacred figures and hieroglyphic characters, beautifully cut in the hard granite, have the sharp finish of yesterday. The very stone looks not discolored.

Although the temples and other edifices of the Egyptians were painted with rich, bright colors, the character of their architecture was grave and sublime. "No people," says Champollion, "either ancient or modern, ever conceived the arts of architecture and sculpture on so sublime a scale as the ancient Egyptians. Their conceptions were those of men a hundred feet high."

The straight lines and angles, unbroken by a single curve, give to the outlines of their structures a heavy, massive appearance, and while there is a general resemblance in the plan of their edifices, there is infinite variety in detail.

They must have been a very numerous people and under severe despotism. Whether the despotism that could command such immense power was that of a cunning priesthood or a long line of ambitious monarchs, is uncertain. Probably the former, as most of the remains are temples dedicated to the worship of their deities. It is said that the wily priests exacted the hard earnings and ceaseless toil of millions to support an absurd, a monstrous, system of idolatry. To keep the people in awe and maintain their blind adoration, the temples of their idols must be imposing and magnificent. Thus what was at first a useful art became the most expensive and, considering the objects to which it was devoted, the most useless.

Yet, to the historian and architect, these grand remains are not useless, for they contain the chiseled record of the manners, customs, arts, sciences, literature, and religion of a portion of the human race which would otherwise have been buried in oblivion.

The ancient edifices of Hindostan resemble those of Egypt in form and general character, yet are sufficiently marked to produce a peculiar style. The stupendous and magnificent temples of the Hindoos, many of which were hewn out of perpendicular rocks, must have been constructed downward till the temple was finished where the foundations remain immovably fixed—a part of the primitive rock.

"The first view of the desolate religious city of Ellora," remarks Mr. Erskine, "is grand and striking, but melancholy."

The number and magnificence of the subterranean temples, the endless diversity of sculpture, the highly wrought pillars, rich mythological designs, sacred shrines, and colossal statues, astonish but distract the mind. No trace, he says, remains to tell us the hand by which they were designed, nor the powerful nation by which they were completed. The empire whose pride they must have been has passed away, and left no memorial behind.

The beautiful ruins of Persepolis, probably the summer palace of a monarch, which Alexander partly destroyed, afford a fine specimen of ancient Persian architecture. Le Brun, who spent three months in exploring them, conjectures that Darius and Xerxes were the builders. Others think Persepolis was built by Egyptian architects. That there was communication of architectural knowledge between the three countries possessing the most magnificent specimens of art cannot be doubted. The Jews, or Israelites, appear not to have gained much celebrity as architects, if the representations of King Solomon's temple we so often see are truthful. A seeming want in design has been concealed by everything costly and dazzling in decoration. In addition to this, it is said that when Solomon was about to build the structure, the workmen of his own kingdom were not sufficient for the task, and those of other nations were employed.

In China, the earliest attempts in architecture and building were close imitations of tents, and to this day there has been no departure from the original design. The discovery of ruins in Central America, immense in extent and perfectly anomalous in style, excited throughout Europe and our own country the most extravagant expectations. Scientific men looked for revelations of a race older than the Assyrians or Babylonians, but there are not sufficient grounds for belief in the great antiquity ascribed to them. In Greece, the land of the sage and philosopher, architecture reached its sublimest height. It is claimed by some to be the base of all the arts, and the one which first announces a degree of civilization, taste, and intelligence in a nation. Grecian architecture bears sufficient resemblance to the best specimens of the Egyptian to demonstrate that they had studied and improved upon that, and in their temples and public buildings their genius and art excelled that of all other nations. One of the most magnificent temples at Athens, dedicated to Jupiter Olympus, was built of the purest white marble. Art, in the zenith of her glory, could present no prouder shrine. Vitruvius says: "This structure is not spoken of with common praise. The excellency and sagacious contrivance have been approved in the assembly of the gods."

Among the Romans, the first efforts of architectural skill were employed upon walls of defense. The unadorned works, constructed during the early ages, were remarkable for solidity. They were built of large blocks of stone in the most substantial manner, thus proving the early ambition which projected, from its very infancy, the Eternal City, the capital of the world. It is said little can be granted the Romans as inventors, either in religion or architecture. They were simply imitators of the Greeks. Some claim the arch is a Roman invention, but arches have been discovered in ruins older than Rome itself. Splendid remains testify how successfully they employed principles acquired from the Greeks. These remains are public roads, aqueducts, temples, theaters, tombs, historical monuments, and forums. The Pantheon, their most celebrated temple, was completed twenty-seven years B. C. It was allowed to remain by the Catholics, who gloried in its conversion to Christianity. Among churches, St. Peter's surpasses any, ancient or modern. Three centuries and a half this cathedral was building, while the cost is estimated at $49,728,000. The base of the dome is 200 feet above the surface of the ground, and rises with its lantern and cross 300 feet higher. This is the wonderful cupola planned by Michael Angelo, one of the boldest attempts of architectural skill. Considering the number of pontiffs who ordered, and architects who planned, it is certainly wonderful that the proportions were kept inviolate, even to the most minute ornament. Michael Angelo left it an unfinished monument of his gigantic power, and his towering genius seemed to watch over his successors until its completion. Nothing ever surpassed, in effect, the interior of this church when illuminated at Easter by a cross of lamps suspended from the center of the dome. All travelers dwell with enthusiasm upon the glory of this scene. Second in magnitude and grandeur is St. Paul's, of London, whose first stone was laid in 1675. Completed in 1710, it was commenced and finished by the same architect, Sir Christopher Wren. The Grecian orders of architecture are largely mingled in both churches. Numerous magnificent churches of great size, built from the seventh to the tenth century and later, are scattered over Europe; St. Sofia, of Constantinople; Peterborough Cathedral, of England, erected by the Normans; Rochester Cathedral, during William the Conqueror's reign, and many others. Many bishops of this period are known to have been skillful architects.

The round towers scattered over Ireland are hobbies among writers. Peter Walsh, in 1664, says they were never known before the eighth century, and were built by the heathen Danes as watch towers. When the Danes were driven from the country, the Christian Irish used them as steeple-houses or belfries. These towers, nearly a hundred in number, are from 50 to 140 feet high.

A number of churches on the Rhine were constructed in the eighth century, and at Lorsch a building still exists which was part of a church consecrated in the presence of Charlemagne, in 774.

During the 12th century, Gothic architecture made its appearance, and was the prevailing style in churches through the greater part of Europe. Whatever its primitive elements, it was created in Northern Europe, and was adapted to the wants of a more inclement sky. If the origins of the Gothic style were various, no less so are the opinions as to the nation to which the invention belongs. It has been ascribed to the Hindoos, Egyptians, Hebrews, Romans, Greeks, Saracens, French, English, Germans, Italians, Spaniards, and Scotch.

The crusades in the 12th century drew the flower of European chivalry to the East, and vast numbers of ecclesiastics accompanied them. Since they were the repositories of art and science during that age, it is more than probable they brought home many novel inventions in architecture. There was also, at this period, a corporation of builders or free masons, consisting of Greeks, Italians, French, Germans, and Flemish, who kept secret the principles of their art, and traveled from place to place for the purpose of building ecclesiastical edifices. They had undoubtedly seen the finest specimens in the East, and would introduce whatever was suitable for Northern buildings, especially in ornamental parts. Some of the best Gothic architecture is found in England, Germany, and France. Westminster Abbey has been called by an English divine "the miracle of the world."

Cologne Cathedral is admired by many as the finest specimen of the Gothic in Europe. The richness of its decoration can scarcely be imagined.

Rheims bosts the most celebrated cathedral in France on account of its historical associations, immense size, and antiquity. The kings of France were crowned in this church, which was founded more than a thousand years ago. Here it was that the unfortunate heroine Joan of Arc placed the crown upon the head of the ungrateful Charles. Some critics, however, consider Amiens Cathedral the perfection of Gothic architecture.

The Spanish cathedrals, though surpassingly rich, lack the grandeur of those in Northern countries. Batalha, the glory of Portugal, was founded in 1385. The cathedral at Milan, a mountain of sculpture, has excited much admiration.

A popular traveler from our own country considers the famous Kremlin at Moscow one of the most extraordinary and beautiful objects ever beheld. It is two miles in extent, and is in itself a city.

Aside from temples and churches, there are multitudes of palaces and public buildings which attest the skill and genius of the architect.

And it will not be amiss to mention some of the noted buildings of our own country. Among these are the Capitol, President's House, Patent Office, General Post Office and Treasury Building at Washington; Girard College, United States Mint, United States Bank, Masonic Temple, and City Hall at Philadelphia; State House, King's Chapel, and the Masonic Temple at Boston; Harvard College; Bunker Hill Monument; St. Paul's, Trinity, Grace Church, St. Patrick's Cathedral, Hall of Justice, in the Egyptian style, Merchants' Exchange, Herald Building, City Hall, Park Bank, and Equitable Life Assurance Building at New York; the State House at Albany; the Washington Monument; the Catholic Cathedral and Merchants' Exchange of Baltimore; and the Custom House, St. Charles Hotel, and Theater of New Orleans. These, with the capitols of the different States and the public buildings of the Northern and Western cities, will compare favorably, and are not surpassed, by structures of like character in Europe. They are lasting monuments to architects of the Old as well as the New World. While some claim that architecture is the base of all the arts, it is unquestionably of civil engineering.

This profession, though considered new by learned writers, was practiced among the Greek six or seven hundred years before the birth of Christ, as is shown by their canals, channels, and aqueducts for the conveyance of water. These were commonly structures of masonry to conduct water across a valley at a high level. Works of this kind are more properly called aqueduct bridges. It is necessary to bear this description in mind when dealing with the undertakings of the Greeks and Romans, for, since the former rarely if ever constructed aqueduct bridges, it has been usual to institute very unfavorable comparisons between them and the Romans, who, with imperial disdain of obstacles, furnished the cities of their immense empire with a series of constructions of this kind which even in their ruins excite astonishment.

True to the difference in national genius, the Greeks followed nature, and seeing the water collected in hills, passing for miles along subterranean courses, then issuing in cool fountains at the coast, adapted their system of conduits to the physical formation of the district; cutting tunnels and canals rather than bridging valleys, and, as a consequence, no conspicuous monument of their system remains. Although they accomplished so little that Strabo is justified in charging them with neglect, in comparison with the Romans, yet it is clear from the records that in this, as in other respects, they were the instructors of the Romans.

The first Grecian aqueducts were constructed 625 years before Christ, and aqueducts, reservoirs, and tunnels were common in Athens 560 years before the Christian era, some of which supply the city to this day, and are described as marvels of enterprise and skill. They are built of stone, some having pipes of baked clay within. The system of conduits in Syracuse, which the Athenians partly destroyed, still supplies the town with an abundance of drinkable water, and the point at which the tunnel passes under the sea to the island of Ortygia presents what is regarded as a remarkable achievement for early times.

At Tusculum is an example of early Italian constructions for the conveyance of water. An oblong basin is divided into channels which receive the water of a spring and distribute it by pipes. The basin is built of blocks of stone overlapping along the sides until they meet and form a roof—a principle afterward supplanted by vaulting, and occurring in the earliest Greek masonry. If, to obtain a proper incline, the water course had to be carried above ground, it was supported on a stone wall, and the conduit built of blocks of stone coated with stucco, impervious to water.

Since a solid wall across a valley would cut off traffic, it was necessary to break it, by means of arches, into a series of pillars, and with this commenced the system of aqueduct bridges, which is the most striking monument of the Roman empire.

Perhaps the best known instance of this double purpose, an archway for traffic over which water can be conveyed, is Porta Maggiore, at Rome. The waters, taken over it in two separate channels, are Aqua Claudia and Anio Novus. From three inscriptions above the arches, it appears that the Emperor Claudius constructed the Aqua Claudia aqueduct from the springs Cacrutus and Curtius, forty-five miles from Rome; and the Anio Novus, from the sixty-second milestone from Rome; and that Vespasian and Titus restored them. Both aqueducts were commenced by Caligula thirty-eight years after the Christian era, and finished by Claudius ten years later. The length was sixty-two miles. Six miles from Rome the Anio Novus approached the Aqua Claudia, and from that point the waters traveled to the city in two channels, one above the other, supported by a chain of arches which at one place reached the height of 109 feet.

The Pont du Gard, as the aqueduct at Nismes is called, consists of three rows of arches striding across the valley of the Gardon. In the lowest row are six arches, one having a span of 75 feet and the others 60 feet each. In the second row are twelve arches, each with a span of 75 feet, while in the third are 36 smaller arches, and immediately above is the water-course. As a bridge, the Pont du Gard has no rival for lightness and boldness of design among Roman remains.

Twelve more aqueducts at Rome, besides those already mentioned, assist in the supply of water. A system of regular reservoirs along the course of the aqueducts enabled repairs to be made at any point, and also let off water for the district they passed. A singular law decreed that material for repairs should be supplied from the private property nearest the damage; and what is still more strange, it was to be conveyed at the expense of the owner of the property. Public spirit or duty was at a high standard in those days; hardly as much could now be expected for the common weal.

Among aqueducts outside of Italy constructed by the Romans, and still existing, the most remarkable, aside from the Pont du Gard, are those at Segovia and Tarragona in Spain. The former is 2,400 feet long, with 159 arches of greatly admired masonry in two tiers, reaching a height of 102 feet; and the latter 876 feet long and 83 feet high. At Mayence are the remains of an aqueduct 16,000 feet long, carried on from 500 to 600 pillars. Similar witnesses of Roman occupation can be seen in Africa and Greece. The aqueduct at Metz, which originally extended across the Moselle, here very broad, conveyed from Gorsa an abundance of excellent water. From a large reservoir at the source of the aqueduct, the water passed along subterranean channels, built of hewn stone, sufficiently spacious for a man to walk upright in. Similar channels received the water six miles from Metz, and conveyed it to the city. The bridge had only one row of arches, and the middle ones have given way, while the others are still perfectly sound. One of the principal bridges of the Antioch aqueducts is 700 feet long and at one point 200 feet high. The lower part consists almost entirely of solid wall, and the upper of a series of arches with massive pillars. Both masonry and design are very rude. The water was drawn from several springs four or five miles from Antioch, and conducted by channels of hewn stone into a main channel of similar construction, and was carried across streams and valleys by means of arches. Many of these old remains now serve as highway bridges, notably that near Spoleto. It has ten arches, remarkable for elegance of design and airy lightness of proportion, each over 66 feet span and about 300 feet in height. The one at Pyrgos, now supplying Constantinople, called the crooked aqueduct, is composed of three rows of arches, is 670 feet long and 106 feet in the deepest part. It conveys the waters of the valley of Belgrade, one of the principal sources of supply. The other is the high ground west of the town, from which the water is conducted by similar conduits. The supply from all sources is 400,000 cubic feet per day.

Egypt and Babylonia presented a different system of water supply. Since both countries were flat and traversed by great rivers, by which they were regularly inundated, canals with large basins took the place of aqueducts. The stupendous scale on which in Egypt the waters of the Nile, and in Babylonia those of the

Tigris and Euphrates, were utilized was a marvel to ancient travelers.

The most remarkable aqueducts in France are those built in the reign of Louis XIV., for conducting water from Marly to Versailles. The famous aqueduct bridge of Maintenon, for conveying the water of the Eure to Versailles, is without doubt, in magnitude and height, the most magnificent in the world. It is 4,400 feet in length, upward of 200 feet high, and contains 242 arcades, each divided into three rows, forming in all 726 arches about 50 feet span. The great works which supply Marseilles with the water of the Durance by a canal 60 miles in length are among the boldest undertakings of modern times. This canal, completed in 1847, is conveyed through three chains of limestone mountains by 45 tunnels, forming an aggregate length of 8½ miles, and across numerous valleys by aqueducts, the largest, Roquefavor, surpassing in size the famous Pont du Gard. This immense volume of water, which passes at the rate of 198,000 cubic feet per minute, is carried across valleys by a channel of mason work, as in the old Roman aqueducts.

In British India, where the fall of rain is scanty and uncertain, artificial irrigation is resorted to. The Ganges canal, traversing the Northwestern Provinces of Bengal, distributes over this vast area nearly the whole volume of the Ganges. It begins where the river issues from the mountains, and 20 miles from its source crosses the valley of the Solani River, where the works for effecting the transit are designed on a scale of great magnitude.

Across the valley is an earthen embankment, raised on an average 17 feet. It has a width of 350 feet at the base, and 200 in the upper part. This forms the bed of the canal, and is protected by banks 12 feet in depth and 30 feet wide at the top. To preserve the banks from the action of the water, lines of masonry, formed into steps, extend on each side the entire length.

The river is crossed by an aqueduct 920 feet long, having side walls 8 feet thick and 12 feet deep. In grandeur of design, solidity, and utility, it challenges competition.

Croton Aqueduct, which supplies New York with water, is the only great work of this character in our country. At the time of its construction, it was justly regarded as one of the most magnificent works of modern times. Its length is 38¼ miles, and it is capable of discharging 60 million gallons per day. It is carried over the Harlem Valley in iron pipes laid upon a magnificent bridge 1,460 feet long, constructed of arches 114 feet above high water.

The water works of Manchester and the aqueduct at Glasgow are in some respects the most stupendous ever constructed, and have attracted a great share of public attention. The most recent, and perhaps most complete in detail, are the Vienna water works, and water supply of Paris.

The Vienna aqueduct is 56⅛ miles long. In order to reduce friction and facilitate the discharge, the inside is plastered with a two-inch coating of Portland cement and sand. This is in three layers, the last a very thin one of pure cement, which when hardened was rubbed with iron plates till perfectly smooth and polished. It was completed in 1873, and supplies twenty million gallons per day.

It is said that Nature is responsible for the planets, but man made Holland. Its history is a subversion of the laws of nature, and its successes illustrate what the science of the civil engineer can accomplish. Fifteen hundred and fifty miles of sea dikes, some forty feet high and broad enough for roadways, are now existing, the result of a constant engineering battle and incessant toil. Nearly the entire region is below the sea level, and the perpetual security can be appreciated when it is remembered that in 1277 a single inundation destroyed forty-four villages, while in 1287 eighty thousand persons were swept away, and its present shape given to the Zuyder Zee. Thousands of acres of fertile land have been recovered from the sea; 12,731 square acres between 1833 and 1877.

In our own country civil engineering has been of the same practical character as in Holland; adding in the largest degree to the prosperity and wealth of the nation.

While we cannot boast so many aqueducts as France or Italy, in number and size our railway bridges are unsurpassed. The age of railroads brought this branch of engineering to a degree of perfection hitherto unknown, especially in the construction of iron and steel bridges. Wooden ones date back to a very remote period. The first we have any account of was built in Rome 500 years B. C. The next was erected by Julius Cæsar for the passage of his army across the Rhine. Trajan's bridge, over the Danube, was made of timber, with stone piers. In the middle ages, when bridges were established as passages over rivers, they were usually constructed with piers, and were more notable for abundance of material than artistic skill. In this country the first wooden bridge of note is the one across the Portsmouth River of 250 feet span. Switzerland has several excellent wooden bridges. The most celebrated, that at Schaffhausen, built in 1757 by a village carpenter, was burned by the French after it had been in use 42 years.

The Romans built the first stone bridge. It was over the Tiber. Twice rebuilt, the remains of the last structure are still visible. Pons Ælius had originally a roof of bronze supported by forty columns. Destroyed by the barbarians, it was restored by Clement IX., who placed on it colossal statues of angels carved in white marble.

In Egypt and India, the birthplace of so many arts and sciences, arched bridges were unknown; neither are they met in the ancient remains of Persia or Greece, though their architecture was the finest in the world.

The first stone bridge over the Thames, known as "old London bridge," was completed in 1209.

The novelty of Westminster bridge was the manner of laying the foundations. This was effected by means of caissons, and inaugurated a new era in bridge architecture.

One of the most remarkable wooden bridges is at Havre de Grace. It is 3,271 feet long, and divided into twelve spans resting on granite piers. Constructed on Howe's plans, it combines great lightness with strength.

Washington Aqueduct bridge has some novel features. Its arches are of cast-iron pipes, which carry the roadway and water supply at the same time. The bridge at Louisville, the truss bridge at Rock Island, the St. Louis bridge and others on the Mississippi, are noted both for design and strength.

Suspension bridges are of remote origin. Kirchen in his "China Illustrated" mentions one of chains supporting a roadway 830 feet in length, built A. D. 65. It is still to be seen.

The Peruvians constructed bridges over the Andes, the principal material being rope made from the bark of trees. Sometimes there were roadways, at others the transit was effected by a basket drawn alternately from side to side.

Iron suspension bridges, however, are of modern date. The first in England was built by Capt. Samuel Brown in 1819, across the Tweed. It was made with 12 chain cables, and the span was 449 feet. Several built in Scotland on the same plan were destroyed by hurricanes.

Pesth suspension bridge was opened in 1849. The clear water-way is 1,250 feet, and the towers 200 feet from the foundations.

In the United States the first one was built between 1796 and 1810, of chain cables. During the last 25 years wire cables have been universally adopted. Roebling's suspension bridges at Niagara and Cincinnati are the finest of this type in the country.

His bridge to connect New York city with Brooklyn is, without doubt, the grandest and most imposing structure in the world. It is 3,475 feet long, 135 feet high, and cost $15,000,000.

The cantilever bridge at Niagara has justly been pronounced a marvel in the science of bridge building. It is almost entirely of steel, and is 910 feet long.

Rush Street bridge, at Chicago, Ill., designed by Mr. Samuel G. Artingstall, is the largest general traffic drawbridge in the world, the roadway accommodating four teams abreast. It is swung by steam power and lighted by electricity. For symmetrical proportions, completeness and elegance of design, it has no rival.

Tunnels are of very ancient origin, and were common in Rome several hundred years before the birth of Christ. 398 B. C., a tunnel, 6,000 feet long, 6 feet high, and 3½ wide, to tap Lake Albanus, was completed in one year.

When Cæsar arrived at Alexandria, he found the city almost hollow underneath from the aqueducts. Every dwelling had its reservoir, supplied by subterranean conduits from the Nile.

The aqueducts of the Romans, Peruvians, and Mexicans included remarkable tunnels.

Among the celebrated tunnels of modern times are Mont Cenis, St. Gothard, Nochistongo, Sutro, Riquivel, Blaizy, Thames, and Medway, and Chicago lake tunnel, which attracted much attention in Europe during its construcion.

Canals are of still greater antiquity. The Assyrians and Egyptians built them first for irrigation, and afterward for navigation. They are now common in all civilized countries, notably in Holland.

Mr. Charles B. Stewart, civil engineer, in his "Lives and Works of Civil and Military Engineers," published in 1871, says that to the United States justly belongs the credit of building the longest canal in the world in the shortest time, for the least money and to the greatest public benefit. The Erie Canal, completed in 1825, is rightly claimed to have exerted an influence that beyond computation excels any investment of money ever made in any nation. Not only great States that border on the great lakes owe their prosperity, but the States beyond the great river Mississippi must forever find their markets through its channels to the Atlantic cities. Other and more rapid modes of transportation have diverted public attention from this pioneer improvement until few are aware that in the extent and value of its tonnage it far exceeds the whole foreign commerce of the United States.

In the remote and far East, many of the earliest and some of the greatest achievements of the architect are of a character to baffle the most learned antiquaries. They are unable to determine for what use or purpose many stupendous structures were created. Had not the library at Alexandria been destroyed, it would doubtless have thrown much light on problems that must forever remain a mystery. And the question is, Has any benefit ever been derived from the construction of these mighty edifices, whose ruins bear silent and solemn testimony of the untold millions which have been expended, and of cruel servitude exacted to gratify the ambition and vanity of kings and tyrants? A country may be richly adorned with temples, palaces, and hanging gardens which surpass even the Garden of Eden, and yet the masses be in the most abject and deplorable condition. To constitute real wealth and power, a country must possess other conditions. Among these are a just and liberal government, which is the foundation of a free and happy people, and great resources, both agricultural and mineral. These, with her manufactures, commerce, public highways, buildings, libraries, and schools, make a nation truly great. Our own country possesses all these in an eminent degree. No nation, ancient or modern, ever made such gigantic strides in public improvements and works as the United States in the last fifty years, and the civil engineer has performed a most conspicuous part in contributing to her wealth and power. There is no uncertainty, no question, in regard to *his* achievements, which bespeak their real purpose to society from the very beginning. As evidence of the benefits bestowed upon society of modern times by engineering skill, it is only necessary to refer to the most noted, the railroads and ocean telegraphs. The first railroad in the United States, known as the Quincy, was constructed in 1826, and the Manchester and Liverpool road was completed about the same time. Up to 1882, Europe had 107,406 miles of railway and the United States 104,813, that of the former being about 2,600 miles in excess of this country. Illinois has the greatest number of miles of any State in the Union, and 504 more than the New England States and New Jersey combined. These roads, extending from East to West, span the continent, making it possible for one to travel from the Atlantic to the Pacific in a number of days that would have been months fifty years ago, and with a degree of ease and comfort inconceivable at that time.

Gigantic mountains, mighty rivers, and deep valleys are no obstacles to travelers or traffic since the skill of the civil engineer has divided continents by ship canals, tunneled the Alps, Hoosac, Alleghanies, and Rocky Mountains; bridged the great rivers of the world and filled valleys; an apparent fulfillment of St. Luke's declaration eighteen hundred years ago, that "every valley shall be filled, and every mountain and hill shall be brought low; and the crooked shall be made straight; and the rough ways shall be made smooth." Could language be more prophetic or more in harmony with the achievements of the civil engineer in the nineteenth century? When civilization and its varied interests made it necessary to have daily and hourly communications between the Old and New Worlds, the electric and naval engineer supplied the want by joining the two continents by a band of iron—the submarine telegraph by which the great commercial and financial transactions of the two continents are largely maintained. Messages of love, sorrow, and respect between friends, and the comity of nations, may be exchanged at pleasure and with the rapidity of the lightning.

It has been said man made Holland; with equal force it can be stated the architect and civil engineer made Chicago, a city whose relationships, characteristics, and rapid growth have no parallel in history. General Watson Webb, lately deceased, in a recent letter to the Hon. John Wentworth, says that in 1822 there was neither house, hut, nor shanty of any kind, except those occupied by the employes of the government, other than those of John B. Beaubien and John Crafts. The first hotel was opened in 1826, when Chicago contained five houses. In 1830 the town was platted, and a year later the population numbered 75, and the cabin hotel gave place to a two-story building called the Sauganash. In 1833 Chicago attained the dignity of an incorporated village. The limits were made on the north to Ohio Street, south to Jackson, and west to Jefferson, and it contained 550 inhabitants and 175 buildings before the close of the year, although there were only 29 voters at the time of organization. Chicago's first public loan, $60, was negotiated in 1834, and applied to making a ditch on each side of Clark Street. In 1837 Chicago became a city, with an area of about 10 square miles, and a population of 4,100. The hydraulic company, designed to supply Chicago with water from the lake, was incorporated in 1848. In the same year the Galena Railroad was begun, which with the Illinois Central, commenced in 1851, was the introductory to that great system now represented by 18 trunk lines, which makes this city the greatest grain, lumber, and provision mart in the world.

In 1857 the grade of the city was raised from 5 to 12 feet. One of the finest opera houses in America was built in 1864, and the lake tunnel begun. The construction of our present system of water supply attracted much attention, not only in our own country, but also in Europe. This was due to the novelty of taking water down from a great lake for domestic and manufacturing purposes. Although tunnels had been constructed hundreds of years before the Christian era, this feature of engineering skill belongs entirely to Chicago and the nineteenth century. Millions have been expended in perfecting this grand system and in the erection of one of the largest pumping engines in the world, whose ponderous movements denote the power and purpose of the designer in supplying to this city one of the most essential elements to mankind with as great a degree of regularity in its pulsation as the human heart in supplying the life-giving current.

In 1871 the city area embraced nearly 36 square miles, and the population was 325,000.

On the 9th of October, 1871, one of the most destructive fires in the world's history occurred, burning over 2,124 acres and destroying 17,950 buildings, thus rendering 98,000 people homeless. Not only has this vast expanse of desolation and ruin entirely disappeared, but a new city has been virtually erected, which is not surpassed in its architectural beauty, number and magnificence of its public buildings and business blocks by any on the face of the globe.

Hon. De Witt C. Cregier, Commissioner of Public Works (our late worthy President), says in his report to the Common Council in 1882, referring to official records of a petition bearing date Aug. 13, 1835:

"Your petitioner respectfully represents to your honorable body, that he has graded and thrown up La Salle Street, between South Water and Lake, in front of lots one and two, and begs to be allowed the cost or value of said work, to be deducted from the taxes of the ensuing year.

"GURDON S. HUBBARD.

"To the Trustees of the town of Chicago."

He adds that the author of this is now a hale and active resident, who has witnessed Chicago grow from a frontier village to its present important place among the great cities of the world.

In his report for 1884 he has suggested public improvements which, if carried out as outlined, will make Chicago the most wonderful city in the world, although less than half a century ago it was nothing but a swamp and quagmire, at seasons impassable to man or beast. Chicago in the future, as in the past, will be the theater of the civil engineer, who has raised her from a marshy slough, paved her streets, constructed her labyrinth of sewers, erected great waterworks and pumping engines, built splendid iron viaducts and drawbridges, one of which has been acknowledged the largest of its kind in the world, and supplied her with a network of street railways which, in detail, are the most complete in the system of street railways. With all these achievements, the city has but entered upon the threshold of her unsolved problems, which will require in their solution still greater power and skill in the engineer, and this hall will be a fitting place to discuss these questions and the plans for their execution. In all probability there are members of this society, and in all likelihood there are some now within sound of my voice, whose names will be enrolled with those of Geddes, Williams, Wright, Douglass, Latrobe, and Roebling, in the future history of the profession and our country. In conclusion, does it not seem fitting to ask Civilization to whom she is indebted for the great achievements which adorn the world; to which of the skilled professions is due the wealth, convenience, and comfort enjoyed by all classes? Without one word of disparagement to any of the noble professions and arts which have contributed so largely to the power and progress of the present age, I repeat, none have left such monuments of wealth, genius, and grandeur as the architect and the civil engineer.

THE PHYSIOGRAPH.

The physiograph is a very ingenious apparatus of Messrs. Delapierre & Vesque's invention. It is a camera lucida for drawing from nature, and consists of two rods and a base that may be taken apart and put into the pocket. One of these rods is screwed into the base, and is provided at its upper extremity with a tube through which the other rod passes. This latter is provided at one extremity with an orifice of small dimensions that contains the camera. Upon looking vertically through this orifice, one sees projected upon the paper beneath an image of what he desires to reproduce—say a landscape, house, or what not—while at the same time he sees the point of his pencil. The focusing is done by raising or lowering the vertical rod. The optical theory of this little instrument is exactly the same as that of the camera lucida.

Let A O and B O (Fig. 2) be two reflecting surfaces, and let M N be an incident horizontal ray. This latter,

Fig. 1.—MODE OF USING THE PHYSIOGRAPH.

after two reflections, must start vertically from the surface, O B, and will follow the dotted line, M N P Q, so that P Q is perpendicular to M N, and the triangle O′ N P is rectangular and isosceles. Then the angle P N O′, as well as N P O′, equals 45°. It is now necessary to seek the angle x formed by the two reflecting surfaces. In consequence of the equality of the angles of incidence and reflection, the equality of the angles a is evident. Then A O is the bisectrix of an angle of 45°. Now, in the triangle N O P, $2a+x=180°$, whence $x=180°-45°=135°$.

If we used but a single mirror inclined 45°, we should obtain a reversed image, while with two the image is righted.

In order that the pencil may be seen along with the image, a screen containing an aperture of the size of the pupil is placed above the mirror, so that about half the pupil sees the reflected image and the other half sees the pencil.

What is original in the apparatus is the substitution of mirrors for a prism. These have not been employed for this purpose up to the present, because no one has thought of that thin glass used by micrographers. In fact, glass of a certain thickness will give two reflections, and with two mirrors we should, therefore, get four non-superposed images. It is necessary, then, that the mirrors be so thin that the different images shall be as close together as possible. The silvering of the mirrors, likewise, contributes to the purity of the image by strengthening two reflections at the expense of the other two. However thin be the mirrors, we shall find by experiment that double reflection is not entirely overcome. This is easily explained by the smallness of the angle a, which is equal to $4\frac{1}{2}°$. But the inventors

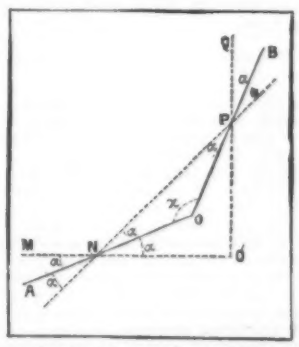


Fig. 2.—THEORY OF THE INSTRUMENT.

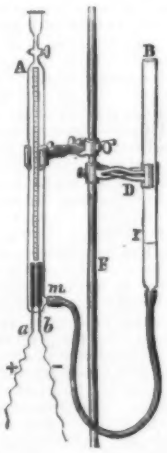
have succeeded in polishing the surface of the silver, and in thus obtaining an image which, although a little less illuminated, is of an irreproachable purity. Fig. 1 shows the manner of using the instrument.—*La Nature.*

MOVEMENTS OF DUST PARTICLES.

This curious and apparently abstruse subject, which may eventually throw new light on various industrial problems, forms the theme of a brief communication recently made to the French Academy by M. Chevreul (*Comptes Rendus*, cl. 2, 13 July, 1885). M. Chevreul has made a series of observations on dust, which was allowed to settle for twelve months on the bottom of a glass vase, the bottom being covered with a sheet of red paper. The dust came from some workshops opposite the laboratory of the Gobelins Works. In these shops cow and calf hair is prepared, being afterward sent to England to be spun, while the skins pass into the hands of the Parisian white-hatting manufacturers. Many years ago M. Chevreul's experiments with guano suggested to him that various substances which come under the notice of the industrial chemist are subject to phenomena of a varied character, which he designates as *expectant*, inasmuch as time is necessary for their manifestation. The results of these phenomena are mechanical, physical, and chemical in their nature. His researches are not sufficiently advanced to enable him to treat the subject fully at present, but he is now satisfied that the phenomena are real enough to be no longer ignored. The dust in question contained at least three different kinds of matters—inorganic matters, the hairs aforesaid, and particles of husks of grain. The dust was deposited in a uniformly smooth layer five millimeters in depth and 30 cent. in diameter, and so left, wholly undisturbed, at the bottom of a glass vase. After a few months one-half of the surface was no longer smooth, but presented spheroidal and paraboloidal protuberances. A few months more, small protuberances began to appear on the other half, as the red paper below showed through. After three months there was an appreciable lowering of the protuberances in the first-mentioned half, and two cylindrical protuberances, each hollow in the center, formed on the line separating the surface into halves. Of these latter protuberances that on the side next the light was the first in turn to disappear. The protuberances seemed to form most readily on the parts of the surface least exposed to light. M. Chevreul had the various phases of the phenomena photographed, and proposes to publish the photographs with a memoir of his researches.

A NEW VOLTAMETER.

In the *Journal of Practical Chemistry*, Mr. Walter describes a voltameter that is constructed according to a principle much employed in chemistry for the measurement of different gases at the same level. In the annexed figure the tube, A, is half an inch wide by 2 inches long, and is provided at its upper extremity with a funnel, separated from it by a glass cock. At the lower extremity of A there is a lateral tube, m, which communicates with the tube, B, through rubber tubing. At the bottom of A two electrodes, a and b, of platinized copper are cemented to the side of the glass. The tube, B, serves for the reception of the water displaced, and for regulating the levels for reading. To this end, the tube, B, carries a clamp that slides along the rod, F. The tube, A, is divided into cubic centimeters, and is provided with a scale engraved upon the glass. To make use of the apparatus, the tubes are filled up to about the middle with water diluted with about $\frac{1}{15}$ its weight of sulphuric acid. After this, the tube, B, is removed, so that A is nearly full. After



closing the glass cock, the height of the liquid in A is read, the level being everywhere the same. After the electric current has passed through the apparatus for some time, the liquid is brought back to the same level in the two tubes by raising or lowering B, and a reading is made of the height by means of the scale on A. The current can also be passed through the liquid for quite a long time without closing the cock, and the measurement not be made until some hours afterward, and without interrupting the current.

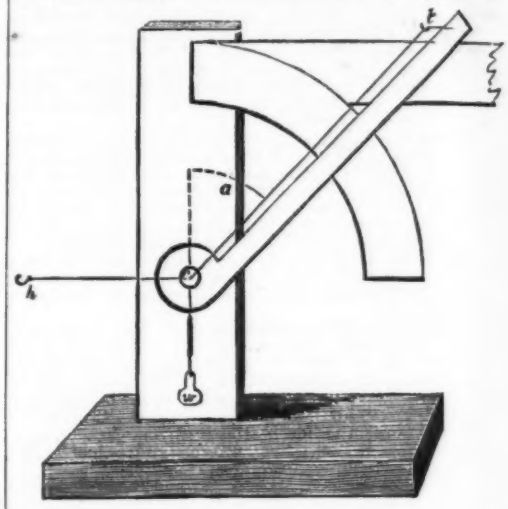
As the liquid diminishes as a consequence of electrolysis, and also through evaporation, the observation cannot be begun with a fixed level, but some datum point must be marked upon the tube, B. We begin, then, by regulating the liquid by raising or lowering B until it is on a level with the datum mark, without concerning ourselves about A, whose surface cannot be distinctly seen, on account of the disengagement of gas. Then the cock is closed, and the circuit broken after a certain length of time, and a reading made as usual. At the end of the experiment we determine the height of the datum mark, r.

When intense currents are operated with, there may be interposed a constant resistance, which is found in the apparatus itself, that is to say, the liquid that fills the rubber tube. In this case one of the electrodes is placed in the lower part of B, and the hydrogen or oxygen is allowed to disengage itself therein.

If a divided scale be put upon each of the tubes, it will be well to graduate one of the latter into cubic centimeters, and the other into 1·5 cubic centimeters. We can thus read directly upon one the quantity of hydrogen contained in the column of detonating gas noted upon the other.—*La Lumiere Electrique.*

AN INSTRUMENT FOR MEASURING FORCE.

Recently, while making some measurements of "force," I experienced the necessity of an appliance



that would increase or decrease the "pull" it exerted smoothly and regularly. To attain this end, I devised the instrument illustrated in the accompanying drawing.

The arm, t c, turns about the center, c, and can be held in any position by the friction of the pivot at c. The three threads, t c, h c, and w c, are joined at c, the length of t c being so adjusted that the joint of the three threads is opposite the pivot of the arm, $t c$. Then, when a weight is suspended at w, the force with which the thread, h c, must be held, in order that the junction of the three threads may remain opposite the point, c, is given from the formula:

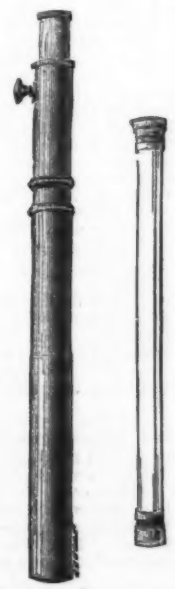
$$f = w \tan. a ;$$

where a is the angle formed by the thread, t c, with the perpendicular; the tangent, a, may be either measured from the tangent scale, or obtained from the quadrant in front of which the arm, t c, moves.

By using different weights at w, and by using stronger threads to measure large forces, or finer threads to measure small forces, the range through which this instrument will measure may be made very great. Thus by using $\frac{1}{16}$ oz. with cocoon silk, and 1 oz. with cotton, and 1 lb. weight with twine; the instrument will measure forces ranging from $\frac{1}{2000}$ lb. to 2 lb. with an accuracy of $\frac{1}{16}$ to $\frac{1}{100}$ part.—*W. Moon, Electrical Review.*

THIERRY'S HEMASPECTROSCOPE.

The apparatus represented in the annexed engraving is designed for ascertaining the existence of infini-



THIERRY'S HEMASPECTROSCOPE.

tesimal quantities of blood in any liquid (such as urine, water, etc.), or for revealing its presence in spots on linen, wood, metals, etc. It is based upon the optical properties of oxyhæmoglobin and reduced hæmoglobin, which give, one of them, two absorption bands situated between the lines D and E of the spectrum, and the

other a single band known as that of Stokes, situated between the two preceding ones.

The apparatus consists of a brass tube in which slides with slight friction another tube of the same metal, that terminates in a spectral apparatus of new design. This latter is provided with a prism of great dispersive power and a diaphragm containing a slit capable of being enlarged or diminished. In the interior of the apparatus may be placed at will three crystal tubes closed at their extremities by two small crystal disks having parallel faces, and fixed by means of a movable collar. These tubes, which measure 4 and 20 inches in length, respectively, and which have a section 0·04 inch square, serve for introducing the liquid to be examined. The tube to be used depends upon the richness of the liquid in coloring matter.

The instrument is either fitted to a hinged base that carries a mirror for sending a fascicle of light into the tube, or simply to an ordinary microscope. For making researches, the mirror of the microscope or that of the standard or base is arranged in such a way as to illuminate the tube brightly; and the slit and focusing are so regulated that upon looking through the eye-piece the spectrum with its well-defined colors may be clearly seen. If solar light be operated with, the Frauenhofer lines should be distinctly seen.

When the focusing has been performed, we take some urine or some liquid in which the supposed blood-spotted fabric or paper has been previously macerated, and put it into one of the tubes. If the liquid be colorless, or the color be weak, we use the 20 inch tube; but if it be deeply colored, we dilute it with water until it becomes of a rosy flesh-color, and then put it into the 4 or 12 inch tube. If the solution were too deeply colored, it would absorb all the light, and the two characteristic bands would consequently be invisible.

Owing to the thick stratum of liquid traversed by the light, the absorption bands make their appearance even with a solution that contains but $\frac{1}{1000}$ of hæmoglobin. A drop of blood of the size of a grain of wheat, upon linen exposed three months to the open air, has, after maceration in sufficient water to fill the 20 inch tube, exhibited the well-marked absorption bands of hæmoglobin. The process is so sensitive that the author has found the absorption bands still perfectly visible in a liquid which, under ordinary circumstances, exhibited no coloration, and which contained but eight drops of blood in six and a half gallons of water.

With urine, the results are almost as satisfactory; but it is very evident that this secretion, colored by itself, prevents the investigation being carried so far. Nevertheless, we find blood in urine which, even after close examination, offers none of the characters of a sanguineous one.

As the tubes are, as we have said, of crystal, the liquids may be submitted to chemical actions that permit of reducing the oxyhæmoglobin, and of verifying its presence through the appearance of the characteristic black band. It is unnecessary to say that this apparatus may be used in all cases where it is possible to apply the process of spectroscopy by absorption, as in the determination of the presence of chlorophyl. It may also be applied for ascertaining the presence of small quantities of ergotized rye in wheat flour, by means of the peculiar absorption spectrum that the coloring matter of ergot of rye gives.—*La Nature.*

BLEACHING VEGETABLE FIBERS.

PROF. LUNGE, of Zurich, has made an improvement in the use of bleaching liquor, which is well deserving of the attention of practical men engaged in the bleaching of cotton goods. It has been repeatedly tried to increase the action of bleaching powder solutions by the addition of reagents which would liberate chlorine or the hypochlorous acid. But the employment of sulphuric, hydrochloric, or even of oxalic acid causes the formation of free chlorine, which reacts too strongly on the fibres, and which very injuriously affects the workmen and the machinery. Carbonic acid does not liberate any chlorine but only hypochloric acid, but, being a gas, is very difficult to employ in practice. It also possesses another drawback, as it precipitates the carbonate of lime on the fiber, and thus makes it necessary to follow with an acid bath. The inventor employs, for the purpose of increasing the action of the bleaching powder, a reagent that, according to him, has not yet been employed, viz., acetic acid, or any other similar weak organic acid, as, for instance, formic acid. The price of acetic acid is not a hinderance for its employment, because small quantities are necessary, as the acid is being constantly regenerated. In the first case, chloride of lime and acetic acid give free hypochlorous acid and acetate of lime. During the bleaching process the latter, in giving up its oxygen, forms hydrochloric acid, which latter, by reaction on the acetate of lime, forms chloride of calcium and free acetic acid, which again reacts on the chloride of lime in the same way as before stated. Therefore a small quantity of acetic acid will be sufficient to effect the reaction. The hydrochloric acid which is formed during the bleaching process will never remain in a free state in the solution, because it reacts at once on the acetate of calcium to set free the acetic acid. This fact is of great importance, since muriatic acid reacts by itself on the fibre it left in contact with the same for any length of time, while, as is well known, acetic acid is completely harmless. As no insoluble lime salts are formed, the souring operations, which generally follow the bleaching, can be well dispensed with; in this case there will not only be a certain economy, but there is also no danger of any mineral acid being left on the fiber by imperfect washing, and therefore no fear of any destruction of the materials, which sometimes occurs with very thick cotton goods. Acetic acid, as is well known, does not act injuriously even at elevated temperatures.

Acetic acid, or any other suitable organic acid, can be employed in different ways, for instance, by adding some acetic acid to the bleaching liquor from the very first, or by a passage through very weak acetic solution after the customary treatment in bleaching liquor; or by bringing the goods in water very slightly acidulated with acetic acid, and in which the bleaching liquor is gradually being introduced by causing the liquids to circulate on the bleaching material. It is stated that if the process be well conducted, a saving in the amount of bleaching powder is effected, and the advantage also gained that the water courses are not so much polluted. If the material to be bleached still contains alkali from the scouring process, or if the water is very hard, or the bleaching solution contains a certain amount of caustic lime, in these cases a moderately large amount of acetic acid would be required for the neutralization of the bases, before the hypochlorous acid would be set free. In this case it is well to neutralize the free alkali or lime very carefully beforehand, by means of either sulphuric or muriatic acid, and then the amount of acetic acid can be added necessary to produce the reaction. The process is suitable for the bleaching of vegetable fibrous materials, either in the loose (raw) state, or as yarn, or cloth, and also for the bleaching of some colored goods, such as alizarin red and other colored materials.

THE IXTLE OR TAMPICO FIBER.

CONSUL CASSARD says: The ixtle or tampico fiber is stout, cylindriform, and, of that kind, one of the strongest known. It has a white-yellowish color, and varies in length from one to three feet, according to localities where the plant grows. The fiber known as *tula* measures an average length of twenty-four inches, and the *yanmave* averages thirty inches. The ixtle is extracted from the leaf of one of the *Agaves mexicana*, to which species belongs the *maguey* or aloe, and much resembles the latter in its form and conditions of

1. Ixtle before blooming. 2. Ixtle after blooming. 3. Leaves before pressing.

growth, although smaller in size. It has also an elongated, sharp, fat, thorn-edged leaf, containing about three parts of aqueous matter and one part of solid, which is all fiber.

On maturing, the ixtle shoots up from its very center a long, round flower-stem, which, on attaining its full growth, falls to the ground, carried by its own weight.

The special botanical name of the plant is not known here. *Ixtle* is its Indian name, and the Spaniards have given to it the local appellation of *lechuguilla.*

It grows wild in the petrean or stony sections of the tablelands of the states of Tamaulipas and San Luis Potosi, and its most extensive fields lie in the vicinity of the towns of Tula and Yanmave; growing with extraordinary exuberance in inexhaustible fields, it is never replanted, and the cropped fields lie in desolate barrenness, with but a few isolated leaves growing sparsely from the old roots.

To become a commercial article the ixtle is submitted to a very simple process of curing, which consists in completely purging from its leaf the aqueous matter, and then in exposing to the sun the cleansed fibers, which are thus dried and bleached.

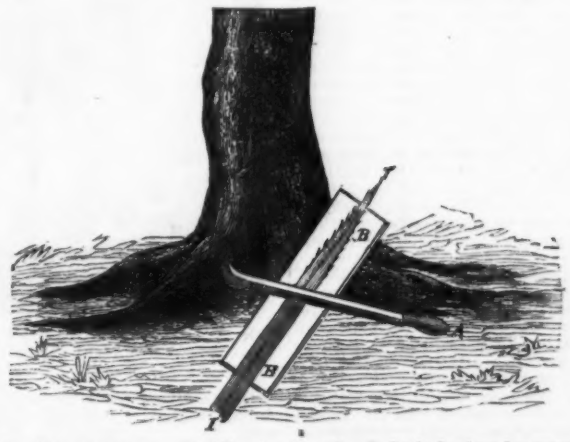
The contrivance used therefor is likewise primitive, consisting simply of a triangular, smooth-edged piece of iron, measuring about sixteen inches long and two inches on each face, with one end terminating in clasp-form and the other as a handle. A board of hard wood is laid at the foot of a tree, and over it, crosswise, is placed the aforesaid iron or presser, its clasp end hooking one of the roots of the tree and the handle end resting in the operator's right hand, with which he strongly presses the leaf against the board, while with the left hand he draws it its full length, repeating the operation until the leaf is completely purged of its aqueous matter.

Through that process an Indian cleans an average of twenty pounds of ixtle per day.

The cutting and curing of the leaves have no special season. These operations are performed while the plants ripen, and this happens during the whole year.

The ixtle is the principal article of export from this section of Mexico. Some 14,000 bales, weighing about 7,000,000 pounds, are annually shipped from this port; 2,000 bales only with destination to the United States, and 12,000 bales are sent to Europe.

Its average price on this market is six cents per pound.—*Wade's Fibre and Fabric.*



A. Iron bar or presser. B. Wooden board. I. Ixtle leaf under pressure.

CONTRIVANCE FOR PURGING THE IXTLE LEAF.

PROF. L. SOHNCKE ON THE ORIGIN OF THUNDERSTORM ELECTRICITY.*

IN order to express more than mere surmises as to the origin of thunderstorm electricity, we must, above all, be familiar with the atmospherical conditions under which thunderstorms usually occur. For this purpose we must first take into consideration two general facts in meteorology: first, the average decrease of temperature with increase of height in free air; and secondly, the nature of the upper clouds.

With regard to the first point, a considerable amount of data is available in the observations of several scientific balloonists, especially those of Mr. J. Glaisher. Glaisher has constructed a table, based upon his numerous ascents, showing the average decrease of temperature for the altitudes of 1,000, 2,000, 3,000 feet, etc. This table shows that even in the warm summer months the temperature of the freezing point is met with generally at the level of between 3,000 and 4,000 meters (say 10,000 to 13,000 feet).

Generally speaking, the aggregate of those points of space in which the temperature of 0° C. prevails at any given moment must lie on a certain surface, which may be denoted as the "isothermal surface of zero C." It is of especial interest to ascertain whether the result yielded by Glaisher's ascents as to the height of this surface in midsummer is confirmed by other ascents. In order to obtain an opinion upon this point, I have grouped together those ascents which afford a sufficient number of data, in order to deduce therefrom the height of the isothermal surface of zero. This table includes twenty-three ascents by eight different balloonists at different seasons of the year; about half of the ascents were made during the summer months. The following are the conclusions drawn from this table:

In the warmest summer months the isothermal surface of zero was found to be at a height of about 3,000 to 4,000 meters, but occasionally sinks even at this season to about 2,000 meters (say 6,500 feet) above the level of the sea. It generally rises in the course of the forenoon, and, apparently, more rapidly the nearer noon is approached. It sinks in the course of the afternoon, and, apparently, more rapidly with the greater distance from noon. Its level may vary about 2,000 meters in from one to two hours. The change from rising to sinking does not occur exactly at noon, but perhaps one hour or even more after noon, according to season.

A knowledge of the decrease of temperature on days of thunderstorms, especially just before the storm, presents therefore especial interest. Only few data exist on this point.

Glaisher made an ascent at 6 P.M. on the 31st August, 1863, after a thunderstorm had taken place at 8 A.M. He did not reach the isothermal surface of zero, but found a temperature of 1° C. at a height of 2,300 meters (say 7,500 feet). I have never found such a low temperature at a similar height in any of the six ascents in August and the beginning of September.

Flammarion made an ascent during the night of the thunderstorm of the 14–15 July, 1868, and met with 0° C. at a height of 2,400 meters (say 6,500 feet), but this was at 4 h. 26 m. A.M. Among all the midsummer ascents there is only one in which the isothermal surface of zero was met with at a lower level.

Welsh made an ascent in the afternoon of the 17th August, 1852, two hours before the occurrence of a thunderstorm; at 5 P.M. the isothermal surface of zero lay at a height of 3,500 meters (say 11,500 feet), but it was rapidly sinking. Welsh did not find such a rapid decrease of temperature upward in any of his other three ascents as in this one.

Kamtz has drawn the conclusion, based upon the great refraction which has often been observed with sultry thunderstorm air, that the rapid change of temperature with height is an important condition for the formation of thunderstorms, especially in summer. In order to obtain more precise data upon this point, I have undertaken a small meteorological investigation as to the difference of temperature existing just before thunderstorms between Freiburg in the Breisgau and the Hochenschwand in the Black Forest, 2,326 feet above it. I found that in seventeen cases which were suitable for comparison, in the years 1880 and 1881, the difference of temperature just before the thunderstorm was less than the average for the day and season in three cases only; in other cases it was greater.

From this it appears that, in most cases, the ab normally rapid decrease of temperature with height, and, in connection with this, the abnormally low position of the isothermal surface of zero, may be taken as characteristic of the condition of weather before thunderstorms.

Secondly, attention must be paid to the nature of

* Extract from "Sitzungsberichte der Jenaischen Gesellschaft fur Medecin und Naturwissenschaft," Jahrg. 1885. Sitzung vom 1 Mai.

the upper clouds, not only generally, but also more especially before thunderstorms. The clouds which lie above the isothermal surface of zero must of course mainly consist of ice particles, although, of course, the formation of clouds of superfused water particles is not excluded. The appearance of the ice clouds is, moreover, somewhat different from that of the water clouds. The former are known as "cirrus" and the latter as "cumulus" clouds. Observations on the height of clouds, made either in balloon ascents or on the ground, agree in showing that the limit of both kinds of clouds in midsummer lies about 4,000 meters (say 13,000 feet) high, which agrees pretty well with the above calculation of the level of the isothermal surface of zero. It is not surprising, therefore, that balloonists frequently reach snow clouds even in midsummer—for instance, Glaisher on June 26, 1863, between 3,300 and 4,200 meters (say 11,000 and 14,000 feet); Fonvielle on July 4, 1875, at 3,450 meters (say 11,300 feet); Barral and Bixio on July 27, 1850, between 4,500 and 6,300 meters (say 15,000 to 20,500 feet); Welsh on August 17, 1850, at 5,990 meters (say 19,500 feet).

While the distinction between ice and water clouds, from their mere appearance as seen from the earth, is always somewhat difficult to be made out, we have in many cases an infallible means of distinguishing between them—namely, by the character of the solar and lunar halos which are very often seen in thin veils of clouds. It has been established beyond doubt that the rings of light of larger size, or halos of about 22° diameter, are caused by refraction in ice crystals. (This angle is that of the least deviation for rays of mean refrangibility in passing through ice prisms of 60°.) On the other hand, the smaller rings (coronæ) of from 1° to 6° diameter owe their origin to the refraction of light through spheres of uniform size. Halos are not nearly so rare as is commonly supposed. M. Galle observed seventy-eight halos and about as many parhelia in a year and a half, and often even in the heat of summer. Kamtz laid great stress on the importance and infallibility of this optical means of distinguishing between the two classes of clouds.

After these preliminary considerations, let us turn to thunderstorms. The local or heat thunderstorms (identical with most summer thunderstorms) are best known, while the large, cyclonic thunderstorms have been less investigated. In the first case, the appearance of the clouds, which rise high in the sky as gigantic columns of cumulus, show that they owe their origin to a strong ascending current of great humidity. According to Dr. Reye, the principal condition for the formation of a continuous ascending moist air current is the abnormally rapid decrease of temperature in its vicinity, while in the current itself the decrease of temperature with height is essentially retarded, owing to the latent heat set free by the condensation of vapor. Under these conditions, the distribution of temperature in the atmosphere is therefore such that the isothermal surface of zero in the ascending current is raised especially high, while outside this current the surface has an abnormally low position. In this way, therefore, water still in a liquid state reaches the ice region; ice clouds and water clouds must exist side by side. If the moist current rises sufficiently high, its temperature sinks below 0° C., and this gives rise to cirrus clouds of snow and hail, which latter frequently accompanies thunderstorms. Kamtz has shown from his observations in high mountains that the height of the locus of thunderstorms must not be placed too low; the usual estimations of the height of thunderstorms based upon observations of lightning and thunder cannot be taken into account here, for they only show (and that very inaccurately) the position of the lowest structure of the thunderstorm clouds.

Both Hann and Kamtz agree that water and ice clouds always exist simultaneously in the sky, and not only during local thunderstorms but also during those of the other kind. Hann describes the layers of "cirrostratus" cloud as always existing with thunderstorms. Kamtz has always been able to recognize halos *i. e.*, the characteristic indication of the presence of ice particles before thunderstorms, as soon as he could trace the change from clear sky to thick clouds. And in all three of the previously mentioned balloon ascents on days of thunderstorms, ice particles have been observed in the air.

We may take it that it has been established that in every thunderstorm clouds composed of water particles and others of ice particles exist simultaneously side by side, and that, of course, they are mutually changing places; it is very easy to suppose that the friction of water particles and ice particles may serve as a source of electricity. But this is in no way a mere supposition, for it is a fact already established by Faraday. In his experiments on the cause of the production of electricity in Armstrong's steam electrical machine, which was considerably modified by him, he frequently caused compressed air to strike against solid objects. The cooling arising from the expansion of the air caused a copious formation of fog, and the friction of these particles against the objects always excited the particles with + electricity and the solid objects with — electricity. It was only by the friction of the particles against ice that the latter became + on every occasion, while wood and metal were excited with — electricity by the friction of the particles.

I have frequently repeated these experiments of Faraday's, and, as was to be expected, entirely confirmed them. Of course, several precautions must be taken if we do not wish to be checked by evidently contradictory results. The principal causes of disturbance may arise by the carrying away of particles of grease from the greasing of the taps, and on the other hand by the friction of the particles on the walls of the tube, if the turning on is not quick enough. In the latter case, the particles become + and communicate this electricity to the objects they meet, and thus, therefore, the character of the electricity by friction with these bodies is partially or wholly masked. The colder the ice, the more powerfully it becomes electrified—a fact which appears to be in connection with the increase of its insulating power with decreasing temperature.

If, therefore, air currents flow against each other, one being of ice particles and the other of water particles, the ice particles become positively and the water particles negatively electrified; and as by no means a rapid mixing of both kinds of air currents is requisite, which may be seen *inter alia* from various observations on smoke-laden air currents in laboratories, the oppositely electrified bodies are quickly repelled from each other.

The real cause of thunderstorm electricity appears to me to lie in the sequence of phenomena above described. It is not my intention to discuss the behavior of the further phenomena connected with thunderstorms.

A more detailed exposition of the theory very briefly sketched here, as well as the observations used for its proof, will be found in my Treatise on the Origin of Thunderstorm Electricity and of the Ordinary Electricity of the Atmosphere, just published by G. Fischer, Jena. ("Der Ursprung der Gewitter-Elektricität, und der gewöhnlichen Electricität der Atmosphäre.")—*Nature.*

NEW ANALOGIES BETWEEN ELECTRIC PHENOMENA AND HYDRODYNAMIC EFFECTS.*

Rings of Different Orders.—We may distinguish different orders in hydrodynamic rings, just as we can in the Newton, Nobili, thermic, and chemical ones. We cannot here, as in optics, count the order of the rings starting from the center, but must, on the contrary, begin at the circumference, as we have had to do with thermic and dynamic rings, which are nevertheless, as regards order of colors, like those of Newton. I shall,

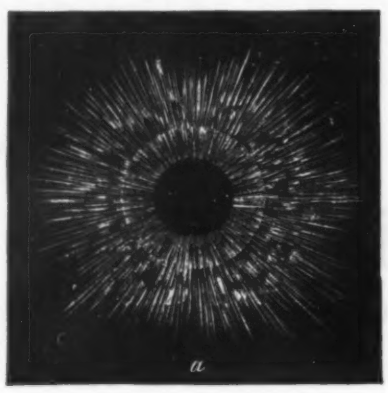
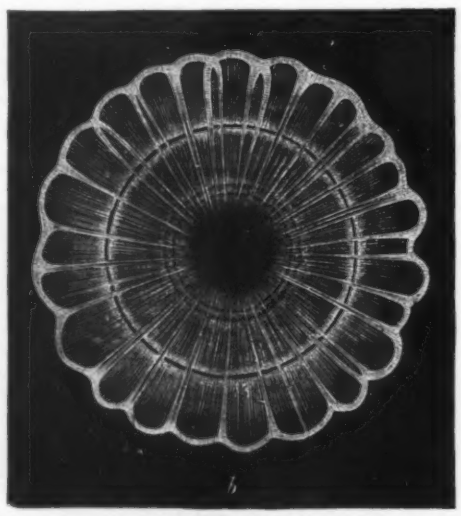


Fig. 1.

then, name as the ring of the first rank the largest one—the one first formed—that which externally limits the figure. The different orders of iridescent rings are not all of equal beauty, and the same is the case with the hydrodynamic ones. Here the ring of the first order has not usually a sharp and regular contour, but often terminates in festoons of very beautiful aspect. The ring of the second order is wide, and the most beautiful, as in thermic ones. In most cases we can distinguish in it radiating lines of varying delicacy. The central rings become narrower and narrower and closer and closer together, and are very sharp and regular. When the fall of the liquid is of some height, say four inches or more, these little central rings disappear through the violence of the current, especially when the pulverulent deposit is very fine or light.

As for the laws of form of the hydrodynamic rings, the laws of the diameters, lengths, and thicknesses, and the laws relating to the influence of the force of the current, of the height of its fall, of the nature and density of the impinging and resistant liquids, of the dimensions of the plate, of the direction of the jet, and the laws of multiple rings, etc., I have not yet been able to determine them, on account of the great difficulties resulting from the non-limitation of the peripheral rings, and from the evolution of the central ones.



Figs. 1 and 2.—HYDRODYNAMIC RINGS WITH RADIATING LINES.

A preliminary examination readily shows that the diameters of the rings do not rapidly increase, and that the different orders of rings of the same figure are not equidistant. Those nearest the center—the last formed ones—are very close together and usually very sharp, narrow, and regular. Those that succeed occupy very wide zones, and embrace the larger part of the space influenced by the impact of the falling current. It should be remarked that the width of the hydrodynamic rings, like that of the thermic and chemical ones, continues to increase from the center to the circumference, while in electro-chemical rings the reverse is the case. The thickness properly so called of the hydrodynamic rings is assuredly much greater than that of Nobili's electro-chemical ones. Yet, with very fine powders, derived from precipitates (such as sulphate of baryta), we obtain figures that are extremely thin, especially toward the center. The thickness of these rings may increase from a light, very transparent, and scarcely visible film to a thick layer that gives relief to the figures, and that is almost impenetrable to light.

It might be thought that by using powders finer than those that I have employed (red lead, vermilion, or sulphate of baryta), and in having recourse to water colors, sepia, India ink, etc., we could obtain better results.

It is true that we produce very pretty effects by this means, but, as an offset, these have one inconvenience, and that is that they are so fugitive that we scarcely have time to see their form exactly, since the liquid, even when quite thick, tends to resume its former level immediately after the impact, and carries along with it the matter in suspension. As a consequence, in a few seconds there no longer remains any trace of the lines that we have just admired the delicacy of. In order to succeed in such experiments, it is necessary to use a heavy powder that the water cannot easily carry along. Then the powder remains in the place whither the propulsive force has driven it, and preserves its form. Yet, if the powder be too heavy, it mixes badly with the water, and cannot distribute itself in a uniform layer over the glass plate. Nobili, in order to obtain good results, mixed his solutions. We might here, with the same object in view, mix heavy and light powders of different colors, in certain proportions, in order to obtain varied effects of fineness and tone.

When we mix a small quantity of gum with the liquid, we render the rings very adherent to the glass, so that they resist a contact of the finger, and have no need of being varnished for the sake of preservation. Unfortunately, such rings are diffuse. Those of the center are still quite marked, but the others are as if covered with a thick veil. Yet it must be stated that the use of gum permits of light powders (such as starch) and water colors being employed, thus giving more sensitiveness to the deposit that receives the impact of the liquid column. But the delicate forms thus obtained become for the most part effaced in the surrounding medium.

The rings obtained by hydrodynamic way usually exhibit slender radiating lines in their structure that sometimes extend from center to circumference. In Nobili's rings we perceive no trace of such lines. This difference disappears when the hydrodynamic rings are produced by the fall of a column of liquid from a feeble height. Then they exhibit only regular circles and continuous zones of varying thickness (Figs. 1, 2, and 3). This result is obtained when, in order to imitate the Nobili process, we leave above the deposit a layer of water into which dips the end of the tube containing the liquid whose fall is to produce the rings. The latter, in this case, closely approach those of Nobili in delicacy of tone. Nobili remarked that with too strong a current the rings were asymmetrical. Under such circumstances, upon a close examination we might perhaps find traces of radiating lines, as in the hydrodynamic rings produced by the fall of a liquid. Perhaps we shall some day discover transverse lines in colored rings, just as we found them in the solar spectrum after the beautiful experiment of Newton.

Hydrodynamic radiating rings call for their counterparts in optics and electricity. We know what we have to look for, and that is something.

Experiments in acoustics have proved useful to optics, and perhaps hydrodynamic experiments may likewise prove useful to electricity. In a recent communication to the Academy of Sciences, Mr. G. Plante has shown that the electric flux is capable of producing varied phenomena, according to the nature of the source whence it emanates—continuous or discontinuous currents from the pile in tension or quantity, discharges of static electricity, induction currents, etc., etc.; so that, according to the source and the arrangements employed, the dominant effects are mechanical, physical (calorific, luminous, magnetic), chemical, or physiological.

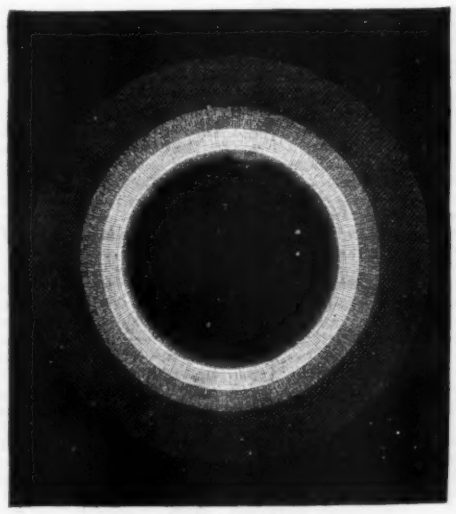


Fig. 3.—HYDRODYNAMIC RING WITHOUT RADII.

In our hydrodynamic imitation of electric phenomena, we, also, have obtained very different and very varied effects, according to the nature and source of the liquid flow used. The correspondence of the effects produced in the two classes of phenomena is easily grasped, and is very significant. With continuous or discontinuous electric currents correspond continuous or discontinuous currents of air or water; and with the spark of static electricity upon a discharge of the Leyden jar or batteries of the same corresponds the fall of a drop or column of water (flowing through a tube) or

* Continued from page 8130.

the impact of a liquid column against a glass plate covered with a layer of red lead mixed with water.

Hydrodynamic figures are analogous to the corresponding figures occasioned by electricity upon an ebonite plate covered with a conducting powder.

On another hand, Mr. Plante shows us the electric flux directly producing mechanical effects like those obtained by hydrodynamic way.

All these analogies, added to those that we have already pointed out, present themselves as new proofs in support of the similarity of the electric flux to a liquid one, the object of our researches.

It must be remarked that our simple hydraulic figures produce many more varieties than those of electro-chemical rings. In fact, these latter all have the same impress, the same shades, and the same forms. The figures obtained by the fall of simple drops or small columns of water upon an aqueous deposit of red lead offer varieties that are, so to speak, infinite. It only requires a slight modification in the thickness or density of the deposit, in the quantity of the liquid falling, in the diameter of the tube, and the height of the fall, to cause very different effects and to produce figures that are extremely remarkable by the regularity of the arrangement of the lines that constitute them, and also to produce arrangements of very pleasing effect. The figures that we have exhibited give some idea of these varied arrangements. They show the evolutionary forms of the annular and radiating arrangements, from the simple right line to the species of flowerets and the complicated festoons that ornament these figures.

The deduction to be drawn from it is that these forms, hitherto without corresponding ones among electro-magnetic phenomena, open up to electricians a new field of research, that is to say, instead of imitating electro-chemical phenomena hydraulically, as I have been doing, we may imitate, by electric way, hydrodynamic phenomena.—*C. Decharme, in La Lumiere Electrique.*

CAUDERAY'S COULOMBMETER.

IN distributions of electric energy of constant pressure or constant potential, it suffices to know the total quantity of electricity furnished to a subscriber for a

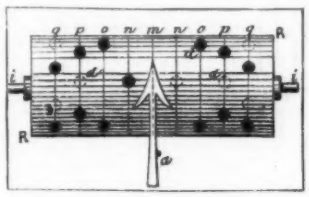


FIG. 2.—PRINCIPLE OF THE APPARATUS.

given time, in order to deduce therefrom the total quantity of electric energy consumed, and consequently what he ought logically to pay for. The apparatus that permit such measurements to be made are called *coulombmeters*, and they constitute two classes according as they are based upon *chemical* or *electro-magnetic* action. Mr. Cauderay's meter, shown in the accompanying engraving (Fig. 1), belongs to the latter class. The principle of it is shown in Fig. 2. R is a cylinder moved by clockwork and revolving around an axis, *i*, at the rate of say one revolution per second. This cylinder, which is like that of a music-box, is provided with pins, *d*, which are arranged upon circles engraved at equal distances from each other upon the surface. The circle, *m*, which divides the cylinder into two equal parts, has no pins. Upon each of the circles, *n*, to the right and left of the center, there is *one* pin; upon the second circles, *o*, there are *two*; upon the third, *p*, *three*, and so on up to the ends of the cylinder; *a* is the needle of an ampere meter whose free extremity stands opposite the center circle, and at a short distance from it. In this position, while no current is traversing the apparatus, the cylinder, R, can revolve without any of its pins touching the needle, *a*; but if a current of say one ampere is traversing the amperemeter, the needle will be deflected to the left or right, according to the direction of the current, and will place itself opposite the circle, *n*. Then, at every revolution of the cylinder, the pin, *d*, of the circle, *n*, will slightly press the needle, *a*, and, by means of a mechanical arrangement, will move forward the needle of a registering device similar to those used in gas meters, and this too by one unit per second, since we have seen that the cylinder, R, revolves once per second. If the current has an intensity of two amperes, the needle, *a*, will place itself opposite the circle, *o*, which has two pins, and, at every revolution of the cylinder, the needles of the meter will register two units, and so on for greater intensities.

In the industrial apparatus the cylinder makes one revolution in a hundred seconds, and, consequently, if the needle chances to be in front of the circle, *c*, for example, it will meet two pins per revolution of the cylinder, and will register two times one hundred coulombs—a quantity which is multiplied by means of a simple dial in order to reach the practical unit of the quantity of electricity, which is here myriacoulombs.

The regulation of the amperemeter is effected by means of screws, which permit of varying the distance between the poles of the needle's magnet, and of thus varying the intensity of the magnetic field of the director. The clockwork movement that drives the cylinder consists of a circular balance regulated to one double oscillation per second.

The shaft carries two armatures of soft iron attracted by electro-magnets mounted in derivation on the distribution. When no current is traversing the electric light apparatus, the balance is at rest. As soon as a lamp is lighted, the current is closed and the electro-magnets give the balance an impulsion that sets the clockwork in motion, and the circuit is broken. The oscillations continue to increase in amplitude, while at the same time remaining isochronous; but, before they become too much reduced, an ingenious mechanism closes the circuit anew and allows the electros to give the balance another impulsion, and so on, as long as there is *one* apparatus in operation in the circuit.

The expenditure of electricity occasioned by the running of the clockwork is insignificant, as the resistance of the bobbins is very great and contacts are rare and short.

The dials are graduated in two ways, according to the application, either into *myriacoulombs* or *lamp-hours*. We take the liberty of criticising this graduation, which responds to no very definite reality, and which has no object but to take advantage of the ignorance of the public.

There are at present incandescent lamps which, with an effective potential of say 100 volts, take from 0·25 ampere to 3 amperes and beyond. To what type of lamp between these extremes will the lamp-hour of the graduation of this meter relate? It would be difficult to say. This entirely empirical graduation ought to be abandoned, then, and the *ampere-hour* be adopted in practice, for this has a very definite value independent of the daily progress of electric light apparatus.

Although the apparatus appears to be complicated, its indications are very accurate, and, from experiments made by Mr. Monnier at the laboratory of the Association for the Study of Electricity, it results that the mean error does not exceed 1·1 per cent., which is insignificant for industrial practice. We have here, then, a convenient means of measuring electric energy; and it now only remains to patiently await the moment when a partial distribution shall permit us to ascertain at Paris the practical advantages of using it. But, unfortunately, it is to be feared that this will not be so very soon.—*E. Hospitalier, in La Nature.*

STANECKI'S PILE.

PROF. STANECKI, of Lamberg, has constructed an interesting pile which has some resemblance to an old invention of Abbot Mocenigo's. The depolarizer used is the oxygen of the air, with which the copper electrodes come into contact very regularly. At the center of a horizontal brass axle that revolves freely between two rings there is a small metallic disk, whose periphery dips into a reservoir of mercury. A small cylinder at one of the extremities of the axle serves to receive a belt, although the axle may also be revolved by a winch. The other extremity carries a small copper disk provided with 16 copper radii of small diameter. These radii form the copper electrodes, and, during the revolution of the axle, dip one after another into the exciting liquid.

A plate of amalgamated zinc is placed lengthwise in the trough, and the latter, when two liquids are used, is divided into two compartments by a porous partition. The conducting wires enter two terminals, one of which communicates with the zinc plate and the other with the mercury. If it be desired to observe the temperature of the liquid, it is easy to add a thermometer. It is unnecessary to say that, instead of revolving the wheel by hand, a motor may be used. Clockwork has been used for the purpose, but the winding of it gave rise to disturbances that were shown by variations in the current. When hydraulic power is at hand, it is easy to connect a series of these elements into a single battery, and operate it. In such arrangements it is an advantage to be able to remove the copper from the liquid as soon as the pile ceases to revolve. The best velocity to adopt depends in part upon the distance between the radii, as well as upon their length.

The proof that it is really the air that acts as a depolarizer is found in the remarkable increase in the intensity of the current.—*La Lumiere Electrique.*

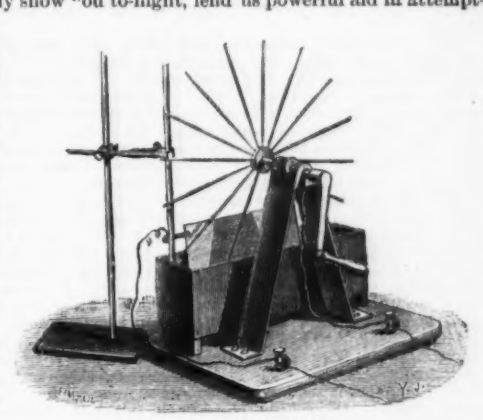
FIG. 1.—FRONT AND BACK VIEWS OF CAUDERAY'S COULOMBMETER.

THE MOTOR CENTERS OF THE BRAIN AND THE MECHANISM OF THE WILL.*

By VICTOR HORSLEY, F.R.C.S.

FEELING deeply as I do the responsibility I have incurred in undertaking to address you to-night, I desire to express my regret that I cannot instead share with you the pleasure of listening to the distinguished man who has been prevented by a most painful bereavement from addressing you to-night.

My subject being the mechanism of the will, it might be asked, "What has a surgeon to do with psychology?" To which I would answer, "Everything." For, without sheltering myself behind Mr. Jonathan Hutchinson's trite saying that "a surgeon should be a physician who knows how to use his hands," I would remind you that pure science has proved so good a foster mother to surgery that diseases of the brain which were formerly considered to be hopeless are now brought within a measurable distance of the knife, and, therefore, a step nearer toward cure. Again, I would remind you that surgeons rather than physicians see the experiments which so-called Nature is always providing for us—experiments which, though horribly clumsy, do, on rare occasions, as I shall presently show you to-night, lend us powerful aid in attempting to solve the most obscure problems ever presented to the scientist.



STANECKI'S PILE.

The title I have chosen may possibly be objected to as too comprehensive; but until we are ready to admit a new terminology we must employ the old in order to convey our meaning intelligibly, although there may be coupled therewith the risk of expressing more than we desire. Thus, when I speak of the mechanism of the will and the motor centers of the brain, I do not intend (as indeed must be obvious) to discuss the existence of the so-called freedom of the will or the source of our consciousness of voluntary power.

I shall rather describe to you first the general plan of the mechanism which conveys information to our brain, the thinking organ; next the arrangement of those parts in it which are concerned with voluntary phenomena; and, finally, I shall seek to show by means of experiment that the consciousness of our existing as single beings, the consciousness of our possessing but one will as people say, while at the same time we know that we possess a double nervous system, is due to the fact that pure volition is dependent entirely on the exercise of the attention which connotes the idea of singleness. Consequently that it is impossible to carry out two totally distinct ideas at one and the same moment of time, when the attention must of course be fully engaged upon each.

I fear that in making my argument consecutive, I shall have to pass over very well-beaten paths, and so I must ask your patience for a few moments while I make good my premises.

The nervous system, which in man is composed of brain, spinal cord, nerves, and nerve-endings, is arranged upon the simplest plan, although the details of the same become highly complex when we arrive at the top of the brain.

At the same time, while we have this simple plan of structure, we find that there is also a fundamental mode of action of the same—a mode which is a simple exposition of the principle, no effect without a cause—a mode of action which is known as the phenomenon of simple reflex action.

The general plan of the whole nervous system is illustrated by this model. Embedded in the tissues all over the body, or highly specialized and grouped together in separate organs, such as the eye or ear, we find large numbers of nerve-endings—that is, small lumps of protoplasm from which a nerve-fiber leads away to the spinal cord and so up to the brain.

These nerve-endings are designed for the reception of the different kinds of vibration by which energy presents itself to us. As the largest example of these nerve-endings, let me here show you one of the so-called Pacinian bodies, or more correctly Marshall's corpuscles, for Mr. John Marshall discovered these bodies in England before Pacini published his observations in Italy. Here you see one of these small oval bodies arranged on the ends of one of the nerves of the fingers, and here you see the nerve-fiber ending in the little protoplasmic bulb which is protected by a number of concentric sheaths.

Pressure (or any form of irritation of this body at the end of the nerve-fiber causes a stream of nerve energy to travel through the spinal cord to the brain, and so we become conscious that something is happening to the finger.

Here in this section of the sensitive membrane of the

* Lecture at the Royal Institution of Great Britain.—*Nature.*

back of the eye, the retina, you see a similar arrangement, only more complicated, namely, nerve-fibers leading away from small protoplasmic masses which possess the property of absorbing light and transforming it into nerve-energy. It is this transformation of nerve-energy into heat, light, pressure, etc., which it seems to me should alone be called a sensation, irrespective of consciousness. And in fact we habitually say we *feel* a sensation. The terms "feeling" and "sensation," however, are frequently used as interchangeable expressions, although, as I shall show you directly, "feeling" is the conscious disturbance of a sensory center in the surface of the brain, and, in fact, feeling is the conscious perception of sensations. This distinction between feeling and sensation, if dogmatic, will save us from dispute as to the meaning of the word "sensation;" and, further, the distinction is one, as I have just shown, which is justified by custom.

Now, the nerve-fiber which conveys the energy of the sensation is a round thread of protoplasm which in all probability connects the nerve-ending with a sensory corpuscle in the spinal cord. These nerve-fibers running in nerves are white, whereas, as you know, protoplasm is gray. They are white because each is insulated from its fellow by a white sheath of fatty substance, just as we protect telegraph wires with coatings. It is not stretching analogy too far to say that nerve-force may probably escape unless properly insulated.

In consequence of the fibers being covered with these white sheaths, they form what is called the white matter of the brain; while the nerve centers are grayish, and, therefore, form what is called the gray matter of the brain, so that the gray matter receives and records the messages conveyed to it by the white insulated fibers.

From the sensory corpuscle, which is a small mass of protoplasm provided with branches connecting it to neighboring corpuscles, the nerve energy, if adequate, passes along a junction thread of protoplasm to a much larger corpuscle, which is called a motor corpuscle, and the energy of which, when liberated by the nerve impulse from the sensory corpuscle, is capable of exciting muscles into active contraction. These two corpuscles form what is called a nerve center.

Not only are the motor corpuscles fewer as well as much larger than the sensory ones, but also the nerve-fibers which go out from them are larger too. In fact, it would seem as if we had another close analogy to electrical phenomena; for here, where we want a sudden discharge of a considerable intensity of nerve force, we find to hand a large accumulator mechanism and a large conductor, the resistance of which may justly be supposed to be low. Finally, the motor nerve-fiber terminates in a protoplasmic mass which is firmly united to a muscle fiber, and which enables the muscle fiber to contract and so cause movement of one or more muscles. Now, with this idea of the general plan on which the whole nervous system is constructed, you will understand that muscular action, *i. e.*, movement, will occur in proportion to (1) the intensity of the stimulation of the sensory corpuscle; and (2) the resistance in the different channels. When a simple flow through the whole apparatus occurs, it is called a simple reflex action, and this was discovered in England by Dr. Marshall Hall.

To recapitulate: a nerve center, theoretically speaking, we find to consist of a sensory corpuscle on the one hand and a motor corpuscle on the other, both these being united by junction threads or commissures. To such a center come sensations or impressions from the nerve-endings, and from such a center go out impulses which set the muscles in action.

I have dwelt thus at length on this most elementary point, because it appears to me that, in consequence of the rapidity with which function is being demonstrated to be definitely localized in various portions of the cerebral hemispheres, we are in danger of losing sight of Dr. Hughlings Jackson's grand generalizations on nerve function, and that we are gradually inclining to the belief that the function of each part is very distinct, and, therefore, can most readily act without disturbing another part.

In fact, we are perhaps drifting toward the quicksands of spontaneity, and disregarding entirely the facts of every-day life, which show that every cycle of nerve action includes a disturbance of the sensory side as well as the active motor agency. Did we, in fact, admit the possibility of the motor corpuscle acting *per se*, and in the absence of any sensory stimulation, we should again be placed in the position of believing that an effect could be produced in the absence of a cause.

For these reasons such a center has been termed kinæsthetic or sensorimotor, and such centers exist in large quantities in the spinal cord, and they perform for us the lower functions of our lives without arousing our consciousness, or only the substrata of the same.

But, now, turning to the brain, although I am extremely anxious to maintain the idea just enunciated that, when discussing the abstract side of its functions, we should remember the sensorimotor arrangement of the ideal center, I shall have to show you directly that the two sides—namely, the sensory and motor—in the brain are separated by a wide interval, and that in consequence we have got into the habit of referring to the groups of sensory and motor corpuscles in the brain as distinct centers. I trust you will not confuse these expressions, this unfortunately feeble terminology, and that you will understand, although parts may be anatomically separated and only connected by commissural threads, that functionally they are closely correlated.

In consequence of the bilateral symmetry of our bodies, we possess a double brain—a practically symmetrical arrangement of two intimately connected halves or hemispheres which, as you know, are concerned with opposite sides of the body, for the right hemisphere moves the left limbs, and *vice versa*.

For my purpose it will be sufficient if we regard the brain as composed of two great collections of gray matter or nerve corpuscles which are connected with sensory nerve-endings, with muscles, and intimately with one another.

In this transverse section of a monkey's brain, which is strained dark blue to show up its component parts, you will see all over the surface a quantity of dark gray matter, which is simply the richly convoluted surface of the brain cut across. Observe it is about a quarter of inch deep, and from it lead downward numerous white fibers down toward the spinal cord. The surface of the brain, the highest and most complicated part of the thinking organ, is called the cortex, bark, or rind, and in it are arranged the motor centers I am about to describe. These white fibers coming away from it to the cord not only are channels conveying messages down to the muscles, but also carrying messages from the innumerable sense corpuscles all over the body.

So much for one gray mass of centers. Now, down here at the base of the brain you see two lumps or masses of the same nature, and these are called, therefore, the basal ganglia or gray masses. Since they are placed at the side of the paths from the cortex, and undoubtedly do not interfere with the passage of impulses along those paths, we may put them aside, remembering that they probably are concerned with low actions of the nervous system, such as eating, etc., which are popularly termed automatic functions.

In this photograph of a model made by Prof. Aeby, of Berne, you see represented from the front the two cerebral hemispheres, with the centers in the cortex as little masses on the surface, and the basal ganglia as darker ones at the bottom, while leading from them down into the spinal cord are wires to indicate the channels of communication.

Note, in passing, that both hemispheres are connected by a thick band of fibers called the "corpus callosum." It is, I believe, the close union thus produced between the two halves that leads in a great measure (though not wholly) to consonance of ideas.

The arrangement of the fibers will be rendered still clearer by this scheme, in which the cortex is represented by this concave mass, and the fibers issuing from the same by these threads.

The basal ganglia would occupy this position, and they have their own system of fibers.

I will now leave these generalizations, and explain at once the great advance in our knowledge of the brain that has been made during the last decade. The remarkable discovery that the cortex or surface of the brain contained centers which governed definite groups of muscles was first made by the German observers Hitzig and Fritsch; their results were, however, very incomplete, and it was reserved for Prof. Ferrier to produce a masterly demonstration of the existence and exact position of these centers, and to found an entirely new scheme of cerebral physiology.

The cortex of the brain, although it is convoluted in this exceedingly complex manner, fortunately shows great constancy in the arrangement of its convolutions, and we may, therefore, readily grasp the main features of the same without much trouble.

From this photograph of the left side of an adult human brain you will see that its outer surface or cortex is deeply fissured by a groove running backward just below its middle, which groove is called the "fissure of Sylvius," after a distinguished mediæval anatomist. This fissure, if carried upward, would almost divide the brain into a motor half in front and a sensory half behind.

Of equal practical importance is another deep fissure which runs at an open angle to the last, and which is called the "fissure of Rolando." Rolando being another pioneer of cerebral topography. Now, it is around this fissure of Rolando that the motor side of the centers for voluntary movement is situated; and when this portion of the cortex is irritated by gentle electric currents, a constant movement follows according to the part stimulated.

Because of their upward direction, the convolutions bounding the fissure of Rolando are called respectively the "ascending frontal" and "ascending parietal" convolutions.

Now, here, at the lowest end of the fissure of Rolando, we find motor areas for the movement of both sides of the face; that is to say that, as regards this particular piece of the cortex, it has the power of moving not only its regular side of the face, the right, but also the left—that, in fact, both sides of the face move by impulse from it.

Higher up we find an area for movement of the opposite side of the face only. I reserve for a moment the description of this portion of the brain, and pass on to say that above these centers for the face we find the next is for the upper limb, and most especially the common movement of the upper limb, viz., grasping, indeed the only forward movement which the elbow is capable of, namely, flexion. The grasping and bringing of an object near to us is the commonest movement by far, and we find here that this center is mainly concerned in it. Behind the fissure of Rolando, Dr. Ferrier placed the centers for the fingers.

Next above the arm area is a portion of the cortex which moves the lower limb only, and in front of this again is an area for consonant action of the opposite arm and leg.

Let me here remind you that this being the left hemisphere, these are the centers for movement of the opposite, that is, the right limbs, and that in the other hemisphere there are corresponding areas for the left limbs.

Thus here we have mapped out those portions of the cortex which regulate the voluntary movement of the limbs. So far I have omitted mention of the muscles of the trunk, namely, those which move the shoulders, the hips, and bend and straighten the back. Dr. Ferrier had shown that there existed on the outer surface of the cortex, here, a small area for the movement of the head from side to side.

Prof. Schafer and myself have found that the large trunk muscles have special areas for their movement, ranged along the margin of the hemisphere, and dipping over into the longitudinal fissure. Thus all the muscles of the body are now accounted for, and I will first draw special attention to the fact that they are arranged in the order, from below upward, of face, arm, leg, and trunk

The consideration of this very definite arrangement led Dr. Lauder Brunton to make the ingenious suggestion that it followed as a necessary result of the progressive evolution of our faculties. For premising, in the first place, from well-ascertained broad generalizations, that the highest center, physically speaking, is also the highest functionally and most recent in acquirement, we find that the lowest is the face, and then we remember that the lowest animals simply grasp their food with their mouth. I imagine it is scarcely necessary for me to repeat the notorious confession that our faculties are arranged for the purpose of obtaining food as the primary object of what is called bare existence.

Proceeding upward in the scale of evolution, we next find animals which can grasp their prey and convey it to the mouth, and so we find next to the face area evolved that for the arm.

And so on, the next step would be the development of the legs to run after the prey, and here is the leg center; while, finally, the trunk muscles are dragged in to help the limbs more effectually.

To my mind this idea receives overwhelming support from the consideration of the fact that the higher our centers are, the more they require education; the infant, for instance, in a few days shapes its face quite correctly to produce the food-inspiring yell, yet takes months or years to educate its upper limbs to aid it in the same laudable enterprise. Finally, what terrible probation some people pass through at the hands of dancing-masters before their trunk muscles will bend into the bow of politeness!

Now, to return to the lower end of the fissure of Rolando, to the areas for movements of the face; it was long ago pointed out by the two Daxes and Prof. Broca that, when this portion of the brain immediately in front of the face area was destroyed, the person lost the power of articulate speech, or was only capable of uttering interjections and customary "strange oaths."

In fact, this small portion of the left side of our brains (about 1½ square inches) is the only apparatus for expressing our thoughts by articulating sounds, and note particularly that it is on the left side. The corresponding piece on the right side cannot talk, as it were. This remarkable state of things is reversed in left-handed people. In these the right hemisphere predominates; and so we find that when this portion was diseased, there followed aphasia, as it is called. While, however, the right side customarily says nothing, it can be taught to do so in young people, though not in the aged.

Before leaving these motor areas, let me repeat, by way of recapitulation, that the only truly bilaterally acting areas are those for the lower facial and throat muscles. This is a most important fact, for the idea has recently been propounded that both sides of the body are represented in each motor region of each hemisphere, that is to say, each motor area has to do with the movements of both upper limbs, for example. In support of my contention that this is not in accordance with clinical facts, let me here show you photographs of the brain of a man who was unfortunate enough to suffer destruction of the fibers leading from one motor area. Here you see a puncture in the brain which has caused hæmorrhage beneath the fissure of Rolando and the motor convolutions in front and behind it.

In this transverse section of the same spot you see that the hæmorrhage has plowed up the interior of the brain. Here is the cortical gray matter, but its fibers leading down to the muscles are all destroyed.

Now, in examining this patient I asked him to move his left arm or leg; he was perfectly conscious, and, understanding the question, made the effort as we say, but no movement occurred.

Now, if both sides of the body are represented in each hemisphere, it seems to me that such a case would be impossible, or at least that a little practice would enable the other hemisphere to do the work; but all clinical facts say that, once destroyed, the loss is never recovered.

If we examine this motor region of the cortex with the microscope, we of course find these large corpuscles, which we have learned are those which alone give energy to the muscles.

But you must not imagine that the motor region consists solely of these corpuscles. On the contrary, as you see in this diagram, we have several layers of corpuscles. I shall return to this arrangement of the corpuscles directly.

Looking back at the surface of the brain, you notice that I have only accounted for but a small portion of the cortex. Dr. Ferrier was the first to show that the portion of cortex which perceived (and I use the word in its strictest sense) the sensation of light was this part, and it is therefore called the "visual center or area." From recent researches it would appear that we must 'give it the limits drawn on this diagram. Below it we find the center for hearing.

Thus we know where two-sense-perceptive centers are situated.

Microscopical investigation shows that this sensorial portion of the cortex is very deficient in large corpuscles, and is correspondingly rich in small cells. Here in this diagram you see these two kinds of structure in the cortex cerebri. Note the greater number and complication of the small corpuscles in the sensory part of the cortex, and the comparatively fewer though much larger corpuscles in the motor region.

It seems to me that several beliefs are justified by these facts.

In the first place, the movements produced by the action of these motor centers are always the same for the same center; consequently, it has only one thing to do, one idea as it were. Thus, for instance, bending of the arm; this action can only vary in degree, for the elbow will not permit of other movements. Hence we may look upon it as one idea. Now, observe that where one idea is involved, we have but few corpuscles.

Next consider the multitude of ideas that crowd into our mind when we receive a sensation. One idea then rapidly calls up another, and so we find anatomically that there are a corresponding much greater number and complication of nerve-corpuscles.

To sum up, I believe we are justified in asserting that where in the nervous system a considerable intensity of nerve-energy is required (*e. g.*, for the contraction of muscles), you find a few large corpuscles and fibers provided; and that where numerous ideas have to be functionalized, there numerous small corpuscles are arranged for the purpose.

But now the special interest attaching to the sensory perceptive areas is that they, unlike the motor areas, tend to be related to both sides of the body. With our habit of constantly focusing the two eyes on one object, it will strike you at once that habitually we can only be attentively conscious of one object at a time, since both eyes are engaged in looking at it, and, as you know, we cannot as a matter of fact look at two things at once.

Hence, I take it, both sensory perceptive centers are always fully occupied with the same object at the

same moment, and that therefore we have complete bilateral representation of both sides of the body in each hemisphere. As a further consequence, each sensory perceptive area will register the idea that engaged it; in other words, both centers will remember the same thing. Thus it happens that each sensory area can perform the duty of the other, and therefore it is a matter of comparative indifference whether one is destroyed or not; and as a matter of fact when this happens we find that the person or animal recognizes objects as they actually are, and in fact has no doubt as to their nature. Here you see anatomically the reason of this peculiarity is found to be that the optic or seeing nerves cross one another incompletely in going to each hemisphere, and thus each sensory center represents half of each eyeball.

I must pass rapidly to the description of the rest of the surface of the brain—the hinder and front ends. At the outset I must admit that all our knowledge concerning them is very hypothetical in the absence of positive experimental results.

This much we can say, that they are probably the seats of intellectual thought, for many reasons which I have not time to detail. Further, we know that these intellectual areas are dependent for their activity entirely on the sensory perceptive centers, for the dictum that there is no consciousness in the absence of sensory stimulation is very well established, as I shall now show you, however astounding it may appear. In the first place, you will remember that when we wish to encourage that natural loss of consciousness which we call sleep, we do all we can to deprive our sense-organs and areas of stimulation; thus we keep ourselves at a constant temperature, we shut off the light, and abolish all noises if we can. But a most valuable observation was made a few years ago by Dr. Strumpell, of Leipzig, who had under his care a youth, the subject of a disease of the brain, etc., which, while destroying the function of one eye and ear, besides the sensibility to touch over the whole body, still left him when awake quite conscious and able to understand, etc., using his remaining eye and ear for social intercourse. Now, when these were carefully closed, he became unconscious immediately, in fact slept, and slept until he was aroused again, or awoke naturally, as we say, after some hours.

Hence the higher functions of the brain exercised when that organ is energizing the reasoning of the mind are absolutely dependent upon the reception of energy from the sense-perceptive areas.

But my only point with reference to this part of the brain is to attempt to determine how far they are connected with the motor centers in the performance of a voluntary act. With the mechanism of choice and deliberate action I have nothing to do, but there can be no doubt that the part of the brain concerned in that process of the mind is directly connected with the motor region, as indicated on this diagram, to which I would now return. From what I have here written you read, arranged schematically, the psychical processes which for the sake of argument we may assume are carried on by the mind in these portions of the cortex.

I wish to point out that we have structurally and physiologically demonstrated with great probability the paths and centers of these psychical actions. There is no break; the mere sight of an object causes a stream of energy to travel through our sense areas, expanding as it goes by following the widening sensory paths here represented, and at the same time we feel our intellect learns that new ideas are rising up and finally expand into the process of deliberate thought, concerning which all we know is from that treacherous support, namely, introspection.

Then comes impulses to action, and these follow a converse path to the receptive one just described; the nerve energy is concentrated more and more, until it culminates in the discharge of the motor corpuscles. We might represent the whole process of the voluntary act by two fans side by side, and the illimitable space above their arcs would serve very well to signify the darkness in which we sit concerning the progress of intellectual thought.

What I have hastily sketched is the outline of the process of an attentive or voluntary act. I say attentive advisedly, for I wish now to put forward the view that the proper criterion of the voluntary nature of an act is not the mere effort that is required to perform it, but is the *degree to which the attention is involved*. The popular view of the volitional character of an act being decided by the effort to keep the action sustained is surely incomplete, for in the first place we are not seeking to explain our consciousness of an effort, we endeavor to discover the causation of the effort. Our sense of effort only comes when the will has acted, and that same sense is no doubt largely due to the information which the struggling muscle sends to the brain, and possibly is a conscious appreciation of how much energy this motor corpuscle is giving out.

Now, to give you an example. I see this tambour, and decide to squeeze it, and do so. Now, this was a distinctly voluntary act; but the volitionary part of it was not the effort made, it was the deliberate decision to cause the movement.

I may now point out that in this whole process we say, and say rightly, that our attention is involved so long as we are deliberating over the object, that as soon as another object is brought to us our attention is distracted, that is to say, turned aside.

All writers are agreed that the attention cannot be divided, that we really only attend to one thing at once.

It seems to me that this is so obvious as not to require experimental demonstration, but I have led up to this point because I now wish to refer to the third part of my subject, namely, the question as to whether we have a really double nervous system or not; but by way of preface let me repeat that, although we may have a subconsciousness of objects and arts, that subconscious state is true automatism, and that such automatic acts are in no sense voluntary until the attention has been concentrated upon them. For example, again I press this tambour because I desire to raise the flag, and I keep that raised while I attend to what I am saying to you. My action of keeping the flag raised is only present to my consciousness in a slight or subordinate degree, and does not require my attention, deliberate thought, or choice, and therefore, I repeat, is not a voluntary action, in fact it could be carried on perfectly well by this lower sensorimotor center, which only now and then sends up a message to say it is doing its duty, in the same way as a sentry calls out "All well" at intervals.

But to return. In consequence of the obvious fact that we have two nerve organs, each more or less complete, some writers have imagined that we have two minds; and to the Rev. Mr. Barlow, a former secretary of this institution, is due the credit of recognizing the circumstances which seem to favor that view. It was keenly taken up, and the furor culminated in a German writer (whose name, I am ashamed to say, has escaped me) postulating that we possess two souls.

Now, the evidence upon which this notion rests, that the two halves of the brain might occasionally work independently of one another at the same moment, was of two kinds. In the first place, it was asserted that we could do two different things at once, and in the second place, evidence was produced of people acting and thinking as if they had two minds.

Now, while of course admitting that habitually one motor center usually acts at one moment by itself, I am prepared to deny *in toto* that two voluntary acts can be performed at the same time, and I have already shown what is necessary for the fulfillment of all the conditions of volition, and that these conditions are summed up in the word attention.

Further, I have already shown that, when an idea comes into the mind owing to some object catching the eye, both sensory areas are engaged in considering it. It seems to me I might stop here, and say that here was an *à priori* reason why two simultaneous voluntary acts are impossible; but as my statements have met with some opposition, I prefer to demonstrate the fact by some experiments.

The problem, stated in physiological terms, is as follows:

Can this right motor region act in the process of volition, while at the same time this other motor area is also engaged in a different act of volition?

Some say this is possible; but in all cases quoted I have found that subconscious or automatic actions are confused with truly voluntary acts. I mean that such automatic acts as playing bass and treble are not instances of pure volition, as the attention is not engaged on both notes at once.

Consider for a moment the passage of the nerve impulses through the brain that would have to occur. At the outset we find that the sensory perceptive centers would have to be engaged with two different ideas at once; but Lewes showed long ago that introspection tells us this is impossible, that "consciousness is a seriated change of feelings," he might equally well have said ideas. And again, we know that when two streams of energy of like character meet one another, they mutually arrest each other's progress by reason of interfering with the vibration waves.

I will show directly that this is actually the case in the action of the cortex when the above-mentioned dilemma is presented to it.

The experiment I have devised for this purpose is extremely simple.

A person who is more or less ambidexterous, and who has been accustomed for a long time to draw with both hands, attempts to describe on a flat surface a triangle and circle at the same moment. I chose these figures, after numerous trials, as being the most opposite, seeing that in a triangle there are only three changes of movement, while in a circle the movement is changing direction every moment. To insure the attempt to draw these figures simultaneously succeeding, it is absolutely necessary that the experimenter should be started by a signal.

When the effort is made, there is a very definite sensation in the mind of the conflict that is going on in the cortex of the brain. The idea of the circle alternates with that of the triangle, and the result of this confusion in the intellectual and sensorial portions of the brain is that both motor areas, though remembering, as it were, the determination of the experimenter to draw distinct figures, produce a like confused effect, namely, a circular triangle and a triangular circle. If the drawing is commenced immediately at the sound of the signal, it will be found that the triangle predominates; thus, if I determine to draw a triangle with my left hand and a circle with my right, the triangle (though with all its angles rounded off) will be fairly drawn, while the circle will be relatively more altered, of course made triangular. On the other hand, if the two figures are not commenced simultaneously, it will be found that usually the one begun last will appear most distinct in the fused result, in fact will very markedly predominate.

Now, the course of events in such an experiment appears to be clear.

The idea of a triangle and circle having been presented to the intellect by the sensory centers, the voluntary effort to reproduce these is determined upon. Now, if we had a dual mind, and if each hemisphere was capable of acting *per se*, then we should have each intellectual area sending a message to its own motor area, with the result that the two figures would be *distinct* and *correct*, not fused.

The other evidence that I referred to above, which is adduced in favor of the synchronously independent action of the two hemispheres, is from the account of such cases as the following: Prof. Ball, of Paris, records the instance of a young man who one morning heard himself addressed by name, and yet he could not see his interlocutor. He replied, however, and a conversation followed, in the course of which his ghostly visitant informed him that his name was M. Gabbage.

After this occurrence he frequently heard M. Gabbage speaking to him. Unfortunately, M. Gabbage was always recommending him to perform very outrageous acts, such as to give an overdose of chlorodyne to a friend's child, and to jump out of a second-floor window. This led to the patient being kept under observation, and it was found that he was suffering from a one-sided hallucination.

Similar cases have been recorded in which disease of one sensory perceptive area has produced unilateral hallucination.

I cannot see that these cases in any way support the notion of the duality of the mind. On the contrary, they go to show that while as a rule the sensory perceptive areas are simultaneously engaged upon one object, it is still possible for one only to be stimulated, and for the mind to conclude that the information it receives in this unusual way must be supernatural, and at any rate proceeding from one side of the body.

To conclude, I have endeavored to show that as a rule both cerebral hemispheres are engaged at once in the receiving and considering one idea. That under no circumstances can two ideas either be considered or acted upon attentively at the same moment. That, therefore, the brain is a single instrument.

It now appears to me that one is justified in suggesting that our ideas of our being single individuals is due entirely to this single action of the brain.

Laycock showed that the Ego was the sum of our experience, and every writer since confirms him. But our experience means (1) our preception of ideas transmitted and elaborated by the sensory paths of the brain; and (2) our consciousness of the acts we perform. If, now, these things are always single, the idea of the Ego surely must also be single.

ACUTE INFLAMMATORY RHEUMATISM.

By JAMES CRAIG, M.D., Jersey City, N. J.

IN an article appearing in the New York *Medical Record*, April 21, 1883, I speak of the manner in which I was led to the use of hydriodic acid sirup in cases of acute inflammatory rheumatism. The object of the present article is not merely to reiterate what was said in that publication, but to emphasize my entire faith in the efficacy of this treatment by the citation of cases of cure, and the statement that I have yet to find a case in which, the sirup being properly used, it has failed to meet my expectations.

Since the publication of my first article this method of treatment has been employed by a number of physicians with success, shortening the duration of the disease, relieving pain, reducing temperature, and in all cases leaving the patient without heart complications, the remedy preventing exudation and organization of plastic material. I order the sirup in from two to three teaspoonful doses, in a wine-glass of water, every two hours, lessening the dose as improvement takes place, and continuing the sirup for about a week or ten days after symptoms have disappeared, to insure recovery and prevent relapse.

The old method of treatment by the use of bicarbonate of potassium is slow, and its continued use brings about a depraved condition of the system by reducing the amount of fibrin in the blood and destroying the red corpuscles. It also acts as an irritant to the stomach, injuring the mucous membrane and causing loss of appetite. The depraved condition of the blood can be seen in the pale face, pallor of the lips, and enfeebled action of the heart, requiring weeks for the patient to recover from the disease and its treatment. Salicylic acid has had its day and has been found wanting, being replaced by some with oil of gaultheria—salicylic acid in another form.

This acid, from its difficult solubility, allows its crystals to irritate the throat and stomach, and, in some, occasions so much vomiting as to render its continued use impossible.

Sirup of hydriodic acid is a good remedy in subacute rheumatism also, but is not so prompt in its action as in cases of the acute form.

I have tried it in chronic rheumatism, but cannot say that I have observed any good results. In some cases I use a lotion as follows:

℞.	Liq. plumbi subacetatis.....	ij.
	Tincturæ arnicæ.....	ij.
	Aquæ puræ.....	℥iv.

M. Sig. Add one part of the solution to three parts of hot water, and apply saturated flannels to the inflamed joints. It usually gives immediate relief. This solution is of a beautiful yellow color when properly prepared.*

The following are a few of the numerous cases of successful treatment of acute inflammatory rheumatism by the use of the sirup of hydriodic acid:

CASE I.—On December 16, 1880, I was called to see Mary S., aged eight years, who was suffering from a very severe attack of acute rheumatism. The knees and ankles were very much swollen, and the pain was so excruciating that she could not bear the weight of a sheet to touch her legs. Protected them with a barrel-hoop cut in two and crossed. Prescribed sirup of hydriodic acid, in teaspoonful doses, every two hours. The pain was subdued within fifteen hours. Continued treatment for about a week. No relapse.

CASE II.—Mrs. E. P. R., aged thirty-five years, was seized with a chill on January 9, 1883. Began the use of the sirup of hydriodic acid on the 10th, and continued the treatment, in three-teaspoonful doses diluted with water, until the 16th, when the patient was dismissed cured.

CASE III.—Mrs. C. F. C., aged thirty-nine. I was sent for on March 21, 1883, and found her suffering from acute rheumatism; prescribed the sirup in two-teaspoonful doses; continued treatment to the 29th, when I made my last visit, and found my patient dressed, sitting up, and free from pain.

CASE IV.—B. E., aged fifty-five, a merchant, has had rheumatism for many years. I attended him with a subacute attack on the 13th of January, 1884; left him on the 18th free of pain. The medicine was given in tablespoonful doses, every two hours, up to this time, when he was ordered to continue its use in smaller doses and at longer intervals for another week. On the 4th of April, 1885, I was called to attend him with a similar attack. Used the sirup. The pain was still severe on the 5th, so I used the lotion to his hand and knee, which gave immediate relief. The last visit was made on the 8th, at which time he was entirely free of pain and swelling.

CASE V.—Mrs. L. A., aged twenty-seven, was taken with a chill, followed with high fever, on the 21st of January, 1885. I was called on the 22d, and found her suffering with an attack of acute rheumatism, affecting both upper and lower extremities. As usual in such cases, prescribed the sirup in three-teaspoonful doses, every two hours, using the lotion as well. She was relieved in thirty-six hours, and was about the house in one week. Ten days after, I made my last visit. Her husband told me that she had had a relapse from imprudently sitting by an open window. Medicine was repeated, and in four or five days she was again free from pain.

CASE VI.—W. C., aged twelve years, of stout build,

* The tincture of arnica should be made according to the United States Pharmacopœia, and not using the fluid extract of arnica flowers, and making a tincture by the addition of diluted alcohol, as this tincture makes an unsightly dirty-brown mixture.

was seized with rheumatism in knee, ankle, and hand. Saw him for the first visit on February 20, 1885. I prescribed the sirup in two-teaspoonful doses, diluted in water (which should always be done); the lotion was also used in this case. My last visit was made on the 28th, when I left him walking about the house.

Case VII.—S. G. S., aged thirty-eight, clerk, was seized on the morning of the 15th of March, 1885. Commenced the use of the sirup on the evening of the same day; he was free of pain and swelling on the 16th, and went to his business on the 17th. He has had no return.

Case VIII.—J. C., aged fifty-one, has had chronic rheumatism for more than twenty years. About the beginning of March, 1885, he was seized with a violent pain in right knee while walking, followed, after a few days, with heat and swelling. The affected knee was two inches larger in circumference than the other; the trouble was looked upon as a sprain for about three weeks, when rheumatism was suspected. Began the use of the sirup in tablespoonful doses in a gill of water; he felt relief after the second dose; treatment was continued every two or three hours until eight ounces of the sirup were taken, which removed all further trouble. No relapse.

Case IX.—John L., aged forty, coachman, was taken down on May 4, 1885; his knees were very much swollen and very painful. He was given the sirup in tablespoonful doses every two hours, and was able to be around the house in four days and a half. He had a relapse on the 24th of the same month, caused by exposure, and was seized with a chill, and again used the sirup and lotion. Advised the sirup to be continued in decreasing doses and at longer intervals for a week or ten days.

Case X.—J. F., aged forty, conductor. I was sent for on May 29, 1885, and found his right knee and left ankle swollen and very painful. He also complained of pain in his fingers and toes. The sirup was given, in tablespoonful doses, every two hours; the lotion was also used. He was free from pain within forty-eight hours. Dismissed him on the 3d of June without pain or ache.

The following cases were kindly furnished me by my friend, Dr. Conrad Wienges, of this city:

Case I.—*August* 28, 1883.—P. M., engineer, aged forty-nine; subacute rheumatism in both knees and ankles. Gave him two teaspoonfuls of sirup of hydriodic acid every three hours. Dismissed him September 30, free from pain or ache. This patient had several attacks previous to this one, but was always confined to the house from four to six weeks.

Case II.—*June* 16, 1884.—Mrs. L., aged thirty-five; subacute rheumatism in the chest and right shoulder. Two teaspoonfuls of sirup of hydriodic acid every four hours. It relieved the pain entirely in twenty-four hours.

Case III.—*March* 30, 1885.—F. McC., nineteen years old; worker in tobacco factory; acute rheumatism in both knees and ankles. He was ordered two teaspoonfuls of sirup of hydriodic acid, every two hours, in a wineglass of water. At my next visit, on the 31st, he could flex his knees and move the foot with comparative ease.

April 1st.—The swelling had vanished, and the patient was sitting up when I called. He was dismissed on the 3d, cured, and resumed his occupation on the 3d of April.

Case IV.—*May* 7, 1885.—G. E. P., thirty years old; deckhand; acute rheumatism affecting his right shoulder and elbow. The pain was excruciating—so much so that one-fourth of a grain of morphine, every hour for four hours, was given to produce immediate relief. He took two-teaspoonful doses of hydriodic acid every two hours. At my next visit, sixteen hours later, the pain had almost disappeared, and he could move the arm with ease in any direction. On the 9th he was entirely free from pain, and was dismissed, cured, on the 11th.

The following cases were kindly furnished me by Dr. Baumann, House Physician at the New Haven Hospital, New Haven, Conn.:

Case I.—M. F. M., Irish, aged twenty-five; single; painter. Was attacked April 24, 1885, with acute rheumatism in the ankles and knees, and on the 25th it extended to his shoulders, elbows, and wrists. Entered hospital this day; temperature 103° F. The pain was so severe that the slightest movement caused great distress. No cardiac lesions. Ordered sirup of hydriodic acid, one teaspoonful every two hours.

28th.—Patient has improved greatly. Temperature 100°; joints not so painful.

29th.—Improvement continues. Patient got up today.

May 4th.—He is up and around the wards, and has no pain in his joints. Treatment continued.

5th.—Discharged cured.

Case II.—P. M., aged twenty-two years; has been under treatment in the surgical wards since April 28th for gluteal abscess. He had an attack of rheumatism in both wrists and hands, and pain in the chest and back. The pain and swelling were so severe that he could not bear to be touched. Temperature 100°. Ordered salicin, grains xx, every three hours, and sodii bicarb., ʒ ss., every three hours.

May 30th.—No marked improvement, and was transferred to medical wards. Salicin was stopped, and he was given sirup of hydriodic acid, two teaspoonfuls every two hours. Temperature 101·6°. Morphine, hypodermically, had to be administered during the night on account of severe pain.

31st.—Pain diminished; morphine not required. Temperature 101·2°.

June 1st.—Patient slept well without the use of anodynes. Fingers could be moved without pain, but the chest was still painful.

2d.—Patient comfortable; all pain and inflammation have disappeared. He fed himself for the first time to-day. Temperature 100°.

5th.—He was transferred to a surgical ward, and sirup stopped.

8th.—Temperature rose to 100·3°, and another attack threatened. He was given the sirup in the same doses. Next day temperature fell to normal. The sirup was continued a week, and then gradually diminished and stopped.

Remarks.—The patient had previously had several attacks of rheumatism, each lasting from two to four weeks. He had a mitral regurgitant murmur on admission.

The sirup was tried in a number of subacute cases with good results, but was unsuccessful in chronic cases.

I hope that I have thus been able to impress upon the minds of my readers the fact that, by the use of the sirup of hydriodic acid in cases of acute inflammatory rheumatism, our results will be far more satisfactory, and our cases less tedious and uncertain.—*N. Y. Med. Jour.*

HENRI MILNE EDWARDS.

Henri Milne Edwards, one of the greatest French naturalists, died at Paris, Wednesday, July 29, after a severe sickness of a few weeks' duration.

Mr. Edwards was born at Bruges, Belgium, on the 23d of October, 1800, of a family originally from Jamaica, and of which he was the twenty-seventh child. His tastes during youth led him especially to art studies, he being fond both of painting and music. No one at that epoch would have ever suspected that he was one day to become so distinguished in an entirely different line of study. His first start in this direction was due to the influence of his brother William, a member of the Institute, and the author of a remarkable work entitled the "Influence of Physical Agents upon Life." At the instigation of this enlightened guide, and under his direction, he began a course in medicine which ended in 1823. This same year he addressed several memoirs to the Academy of Sciences, one of which, written in conjunction with Breschet, fixed the attention of the scientific world. From this epoch on he devoted himself entirely to the study of the natural sciences, and his numerous and admirable labors year by year shed a new light upon a large number of problems relating to life.

The first naturalists who studied animals endeavored to classify them by an examination of their external characters, a method that was still in vogue when Cuvier appeared. But this illustrious anatomist, in his numerous studies, showed that, as regards the ties

HENRI MILNE EDWARDS.

that connect living beings with each other, external characters possess but a relative value, while those derived from anatomical structure have the preponderance. This new method of proceeding necessarily led to the establishing of classifications that were more accurate than those that had preceded them, and permitted of understanding to a certainty what the animal kingdom was. Edwards, like Cuvier, being desirous of ascertaining the ties that connect the different organisms, made anatomy the basis of his studies, and added thereto a series of researches into the mode of development and operation of the organs. This was the method he used during his entire life, and which led him to the discovery of the laws that preside over the organization of animate beings, and which made him an undisputed master whose teachings soon spread throughout the whole universe.

In 1826, along with Audouin, he began his splendid researches upon the anatomy, physiology, and zoology of marine animals of the coast. These studies were pursued at Saint Malo and Grandville and on the Chaussey Islands during the following years, and in 1830 a resumé of them appeared in two volumes entitled "Littoral de la France."

In 1832 Edwards became professor at the Lyceum Henri IV. and at the Central School of Arts and Manufactures. Despite so much teaching, he got time to prepare and publish numerous works of a popular character, among which was the zoological part of Comte's Elements of Natural History and an elementary book upon zoology. But the study of marine animals was still a strong attraction for him. Up till then, the crustaceans, whose circulation he had just described, had been the object of no general study as regards their organization and their distribution into groups, genera, and species. Struck by the number and the richness of forms of the specimens contained in the Museum of Natural History, where they had been deposited by numerous travelers, Edwards conceived the idea of writing a complete history of these beings. This labor was accomplished with wonderful rapidity, and the results of it were published in two volumes with atlas in 1834.

Two years later we find our naturalist upon the coast of Algeria, whither he had gone to study the organization of various marine animals. Upon his return to France he published his different observations in a series of memoirs bearing the title of "Anatomical, Physiological, and Zoological Researches upon the Polyps" (1838).

The importance, number, and variety of Edwards's labors had early attracted the attention of zoologists, and so upon the death of Cuvier the Academy of Sciences opened its doors to him. During the same year he was put in charge of the course in comparative anatomy and physiology at the Sorbonne.

In 1839, after some researches at Saint Waast and La Hougue upon the English Channel, and some others the next year at Nice, he brought out in a series of memoirs various facts concerning the embryogeny, the comparative anatomy, and the physiology of the ascidians.

In 1841 he was appointed professor of entomology at the Museum, where he succeeded his friend and colaborer Audouin. It was at this epoch that he conceived the notion of extending his researches to deep-sea animals, and his mind became wholly occupied with the idea of those submarine explorations that he had the happiness of seeing accomplished later on by his son Alphonse. Other persons would have halted in the face of the difficulties offered by the new kind of study that he desired to undertake; but his character would not allow him to conceive an idea without realizing it, and so he entered upon an enterprise that was fortunately crowned with success, although it might have cost him his life. As it was not possible with fishing apparatus to capture the animals that existed at the bottom of the sea, he conceived the idea of having himself let down to the bottom in order to observe *in situ* an animal world that up till then had never been contemplated. This project of his was carried out off the coast of Sicily during a voyage of exploration undertaken with Messrs. Quatrefages and Blanchard. He inclosed his head in a sort of helmet provided with valves, loaded his feet with lead, and descended, air being furnished him by a pump on board the boat. The results of this voyage were quite important, and it was at this epoch that he made his admirable researches upon the mollusks.

Upon his return in 1844 he was named titular professor at the Faculty of Sciences of Paris, and, five years later, he assumed the functions of dean, which he retained up to his last day. As dean of the Sorbonne Edwards rendered immense services. In spite of his teaching here and at the Museum, and in spite of the numerous occupations that his deanship imposed upon him, he never ceased his scientific pursuits. In 1850, in conjunction with Haime, he published a work upon the fossil corallarians of Great Britain, and in 1851 he devoted a long memoir to the morphology and classification of the crustaceans. The same year appeared his important work upon the Tendencies of Nature, wherein he gave his views upon the vitality of the various parts of the organism, and wherein he formulated the law of the improvement of animate beings by division of physiological work. After this, he published a monograph of the Fossil Polyps of Palæozoic Deposits, in conjunction with Haime, and a History of the Corallarians properly so called. In 1857 he began the publication of that admirable scientific work entitled Lessons upon the Anatomy and Physiology of Animals. This work occupied him until 1881, and constitutes one of his best titles to fame. Upon the completion of it, his pupils and admirers took up a subscription in order to have a medal struck in his honor. At the same epoch, the Dutch Society of Sciences, having for the first time to award the Boerhaave medal for the most important work done in natural history, designated Edwards as the recipient.

Edwards had for many years been inscribed among the members of the various learned societies of Europe, and the French government, desirous of doing him honor, made him successively chevalier of the Legion of Honor in 1833, officer in 1847, commander in 1861, and grand officer in 1885.

Edwards was ever ready to devote himself to the service of his country. When the cholera was ravaging Paris in 1832, he remembered that he was a physician by profession, and, although he had never practiced, he hastened to put himself at the disposal of the city, in order to offer his services gratuitously to the unfortunate. When war broke out with Prussia in 1870, he was quick to organize the workmen and laboratory servants of the Sorbonne into a company, which, under his direction, rendered great services in throwing up earthworks at Fort Bicetre. During the bombardment he did not cease to expose his life in order to save the Museum collections, and when through the fall of a bomb a fire broke out, he was the first upon the spot to render aid.—*La Nature.*

THE CULTIVATION OF MICROBES.*

We sterilize all our instruments beforehand in erouvettes closed with an asbestos plug, through which the instruments pass. The latter consist of glass pipettes with pointed ends and an aperture at the side above the point (Fig. 1 A). The upper part is provided with a plug of wadding or asbestos. At the moment of using them it suffices to adapt a rubber tube to the upper orifice and to take the pipette from the sealed glass tube, when we have in hand a sterilized instrument that can be used at once, since it is cold. A little of the liquid to be sown is removed and introduced into a culture vessel through the latter's plug. It is only necessary to press the rubber in order to cause a drop of the liquid to fall.

For more solid materials we use knitting needles or platinum wires placed in narrow tubes (with beveled point) that have been previously sterilized (Fig. 1 B). In order to remove the germs we push the wire beyond the extremity of the tube containing them, and then take it out and introduce the whole into a preserving vessel, and, removing the wire anew, we bring it into contact with the nutritive liquid. The sowing is effected without possible contamination on the part of the air or foreign bodies.

When we have to do with an already pure culture, and it is simply a question of propagating from one vessel to another, success will be obtained, by the methods indicated, without any trouble. But in nature we in most cases meet with a mixture of several species, which it becomes necessary to first isolate, so that each of them may afterward be cultivated separately. It is here that we must bring in the method of division, an operation that may be effected in two ways, and that is, by culture liquids and nutritive jellies.

Let us first cast a glance over the operations of division in liquids, as they present themselves according

* Continued from Supplement, No. 491, page 7846.

to our simplified method. The principal instrument is a cylindrical burette tapering at the two ends and so graduated that its lower orifice corresponds very accurately to the mark 100, while the 0 is situated a few centimeters beneath the upper orifice (Fig. 2). The burettes that we employ are of 100 cubic centimeters capacity. To each extremity is fitted a thick rubber tube provided with a pincher. Before using, we disinfect the pipette and rubber tubes by allowing a current of sulphurous acid to flow through them. Then we adapt the pipette to the eduction tube of a digester that has previously been filled with water and heated to 110°. The superheated steam then traverses the pipette, which has been so placed that its free orifice points downward. At the end of a quarter of an hour, every trace of the sulphurous acid will have disappeared, and we then put the pinchers upon the rubber tubes again, *first* upon the eduction one, and next upon the one that leads the steam. A plug of asbestos that has been passed through a flame is put into the

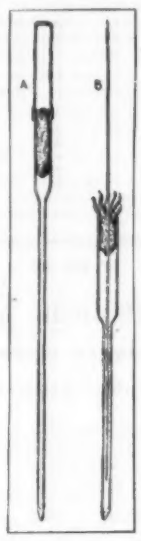


FIG. 1.—PIPETTE AND TUBE WITH PLATINUM WIRE.

mouths of the rubber tubes, and the pipette is then allowed to cool. The steam condenses, and a most perfect vacuum is produced.

To the lower tube we now fit a canula that is sterilized at the same time by a current of steam and by passing it through a flame, and at once introduce this point into a bottle of sterilized broth that has remained for three or four weeks in a culture stove regulated to about 30°. It is only necessary to open the lower pincher to have the broth flow into the empty pipette and entirely fill it. After this, opening the two pinchers, we let the liquid descend as far as to the mark 0, or a little below it.

Things being thus arranged, it suffices to introduce the drop of liquid or bit of substance that it is desired to isolate or count the microbes of, into the burette through the asbestos plug and the rubber tube. This sowing will have to be done with a material sufficiently diluted or in sufficiently small quantity to have the number of germs very small; for the 100 cubic centimeters of broth can scarcely be distributed among

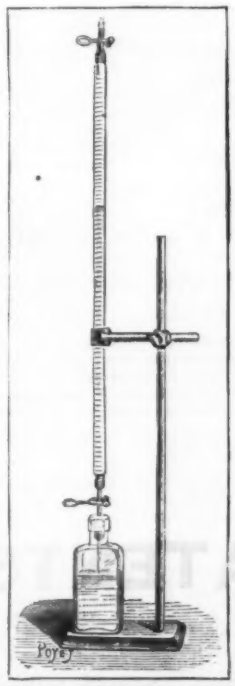


FIG. 2.—FRACTIONAL BURETTE.

more than twenty-five tubes, and the operation will not succeed unless half or a third of these latter remains sterile. It is only under such conditions that we shall be able to count on it that the majority of the tubes that are sown contain but one germ.

If it is a question of determining the number of living germs that a specimen of water contains, it is only necessary to introduce a very accurately measured quantity of it into the burette full of sterilized broth. Upon afterward turning the burette fifteen or twenty times end for end, a perfect mixture of the two liquids will be obtained. The pointed canula, which has been carefully inserted into a sterilized wad, is then, as a measure of precaution, passed quickly through a flame and introduced through the stopper into a sterilized tube. The pincher is now opened, and four cubic centimeters of the mixture allowed to descend; then a second tube succeeds the first without passing the canula through the flame anew, and so on. The mixture is thus soon divided up among twenty-five tubes, which are placed upon a support in a culture stove.

If all the vessels spoil, it will be because the quantity of water to be examined was too great. In this case the operation is begun again with smaller quantities until only a portion of the tube becomes turbid. With water highly charged with germs, it would be necessary to put in so small quantity of the liquid that it would be impossible to measure it accurately. In this case two burettes are prepared, one of them full of water, and the other full of sterilized broth. Into the first is introduced a small quantity of the water to be examined. This is mixed with sterilized water, and a small quantity of this mixture is used for sowing the broth with.

Let us take an example. A water to be examined is supposed to contain from 10,000 to 80,000 germs per cubic centimeter. A tenth of a cubic centimeter of such water is mixed in a burette with ten cubic centimeters of sterilized water. Then one-tenth of a cubic centimeter of the mixture is added in another burette to 100 cubic centimeters of broth. This latter, then, receives only the germs contained in $\frac{1}{1000}$ of a cubic centimeter of the water to be examined. The broth, which is divided up between twenty-five tubes, becomes turbid in five of them and remains clear in the twenty others. There were approximately, then, five germs in the $\frac{1}{1000}$ of a cubic centimeter of the water under consideration—say 50,000, at least, per cubic centimeter.

This method requires a previous approximate knowledge of the richness in germs of the liquid to be examined. Without this it would require long experimentation to reach a result. But we have a means of easily reaching such a preliminary knowledge in a few days, and that by cultures on gelatine, which we shall speak of further along.

Our processes are applicable not only to the separation of germs for reaching absolutely pure cultures, and not only to the counting of the germs in water, but also to the counting of the germs contained in a given volume of air, through manipulations which we shall soon describe.

The first examinations of air by Messrs. Pasteur and Tyndall consisted in opening vessels of broth that had been sealed with a lamp during their ebullition. This rudimentary process was incapable of giving very convincing results. Those that it did give these experimenters were accurate enough, but in unskillful hands

FIG. 3.—GLASS CULTURE BOX.

it has led to errors. The first serious experiments were performed by Mr. Miquel, and consisted in passing, through suction, a given volume of air through U-shaped tubes full of perfectly sterilized broth. The trouble with this method is that it is necessary to find by experiment a quantity of air that contains but one germ, and to cause each tube to be traversed by such quantity. Being given the chances of error that accompany the opening of each of the tubes, such as the fall of a germ attached to the mouth of the tube or of the instrument that serves to open it, and the contamination of the air by the clothing of the operator, or, on the contrary, the loss of germs that fall upon the glass at the mouth of the tube and remain adherent to it, it is evident that this method is open to improvement. These criticisms are not applicable to the new method adopted by Messrs. Miquel and Freudenreich, and which consists in passing a large volume of air through a sterilized wad contained in a glass tube, and then washing the wad in sterilized broth and ascertaining by the fractional culture method the number of germs that the wad has yielded up to the broth. We have but one objection to make to this method. The wad that filters the air may, in the washing, retain a portion of the germs that it contains. Placed in a vessel apart, it will count but for one, while it may have contained several hundred microbes.

In order to avoid this great inconvenience, while at the same time put to profit the great advantages of the method, it has occurred to us to replace the wad with a powder soluble in the chemically indifferent water through which we filter the air. This powder, once dissolved in the sterilized broth, gives up all the germs, and the latter distribute themselves uniformly throughout the water. We use kitchen salt placed in a glass tube between two wads of cotton and sterilized by heat. The sowing is done in a slightly salt broth. The manipulations are simple, and, if the quantity of salt is small, the results are perfectly accurate.

Suction is effected by means of a small portable apparatus heated by a spirit lamp, and the quantity of air that passes is registered by one of those portable gas meters that Mr. Freudenreich was the first to use. The tube that holds the powder is fixed vertically to a support, and the upper wad is removed at the moment of beginning the experiment, and replaced immediately afterward. It is well to use fine spun glass or asbestos for making the wads, so that they can be passed through a flame before putting them into place; and it is well to provide the tube at each extremity with a glass cap lined internally with wadding to prevent the germs from fixing themselves to the glass. It is also necessary to take care to keep far away from the tube during the experiment, for one's clothing is a true reservoir of germs. The best thing to do is to fix the tube to the apex of a photographic tripod connected by a long rubber tube with the meter that we stand alongside of.

In order to afterward determine the number of germs remaining in the kitchen salt, it is only necessary to pour the latter into a burette of broth through its upper orifice, and, after complete solution of the salt, to proceed with fractional cultures, as in the examination of water. The fractional method can never give more than an approximation with nutritive liquid media, but it is precision itself as compared with the results given by the method in which the cultures are made upon gelatine jelly. As an offset, this latter is so convenient that it is scarcely ever abandoned when one has come to know its advantages. It serves for the preliminary experiments connected with the separation of species, which latter are afterward to be isolated by the more accurate fractional method.

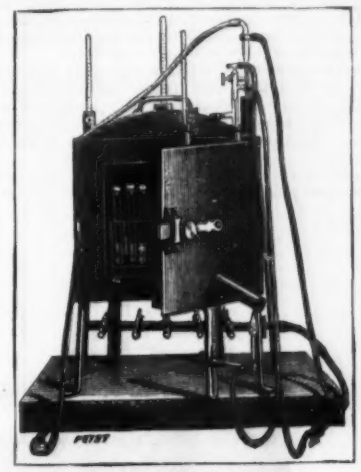


FIG. 4.—WIESNEGG STOVE.

Preparations of nutritive jelly are easily obtained by the methods indicated above. For the preliminary examination of water, a certain quantity of it, say one cubic centimeter, is to be introduced into a jelly. Then the latter is melted in a stove, and after the mixture has been well shaken, it is left to itself in order that it may solidify. If a test glass be used, it must be inclined so that the surface of the jelly may spread out upon an inclined plane, and thus facilitate the counting. But it is much better to use conical bottles or glass boxes of the form shown in Fig. 3. The jelly being spread out in a thin layer upon the bottom of the vessel permits of doing the counting more easily. On the fifth or sixth day there will be observed colonies of very diverse sizes and appearances, which will be especially well seen if the brightly lighted layer be placed in front of a black background. The operation may be shortened by drawing intersecting lines upon the bottom of the vessel. It is necessary to make haste, for on the seventh or eighth day the bacterian colonies will begin to spread out, liquefy the gelatine, and unite all the small colonies that surround them. For atmospheric germs the soluble powder that has served as a filter must be introduced into the melted gelatine.

The figures thus obtained are always less than what they really are. The majority of the germs vegetate but slowly at the ordinary temperature in a solid medium, and are not yet visible at the moment the ex-

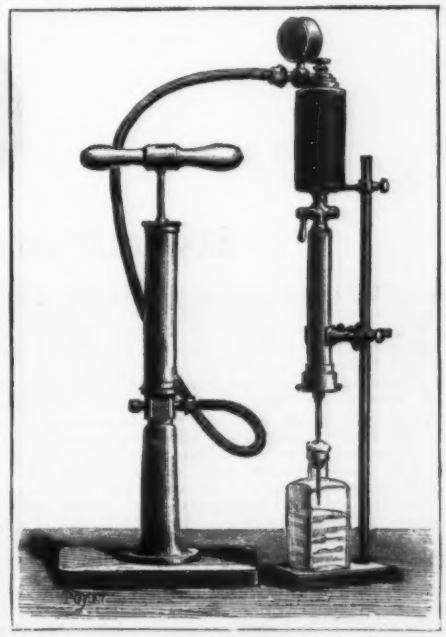


FIG. 5.—CHAMBERLAND FILTER.

tension of a few bacterian colonies obliges us to interrupt operations. After an experiment with gelatine, we usually multiply the figure obtained by 20 or 25, in order to obtain approximately the one that we can take as a guide for the first fractional examinations in the broth. These figures show what little value the method possesses by itself; but, we repeat, as a preliminary test, it economizes time.

For separating germs derived from a pathological

product, the jelly method is the more useful; but its great drawback is that it does not favor the development of a host of species that will prosper in a liquid medium in a stove.

For sterilizing jellies we use a digester. In Germany they employ for this purpose, on the recommendation of Koch, the much less expeditious method of fractional sterilization, invented by Tyndall. In our opinion there is no plausible reason for having recourse to manipulations which require eight days at the least to reach a result that can be obtained with more certainty in two hours.

As an offset, the discontinuous sterilization of Tyndall's is justified when we select as a culture medium a substance coagulable by heat, such as the white of an egg or the serum of blood. In this case only have we recourse to repeated heatings. But we have discarded the use of so inconvenient and impracticable an apparatus as the one invented by Koch, and have substituted for it a stove based upon the same principle, but of different form (Fig. 4). It is a stove with an external jacket, in which the intervening space is filled with water. Two apertures give access to this space, and serve either for filling it or for the insertion of the bulb of a thermometer and gas regulator. The door, also, is double and filled with water, and has its thermometer, its regulator, and its gas burner, which latter is so arranged that the door can be opened without interfering with the heating. The interior is surrounded on all sides, then, by water kept exactly at 75 degrees Centigrade.

The supports, each containing thirty-two tubes of serum, are every day placed in this stove for an hour in order to kill the microbes, and the balance of the time in an incubating stove regulated to 35 degrees in order to favor the germination of the belated spores.

At the end of ten or fifteen days the majority of the tubes show that they are sterile.

But this ingenious method is reduced to the rank of a second-rate one by that of cold filtering through a material of sufficiently fine porosity to retain every germ. Mr. Pasteur long ago obtained such a result by means of plaster filters, but there were so many difficulties and so much uncertainty connected with these that they never came into daily use. The problem is now solved, since Mr. Chamberland has given porcelain filters a really practical form (Fig. 5). Prof. Dunant and ourself have ascertained, through accurately conducted experiment, that this mode of filtering is really efficient when the porcelain tube is of good quality. The filters now in the market are not yet perfect, for some exhibit fissures and others have been too much baked and are impermeable. In the works that Mr. Joly has established at Geneva, under the direction of Prof. Monnier, for delivering to commerce a water perfectly free from microbes, a special apparatus has had to be mounted for testing each porcelain cylinder before using it. We doubt not that the filter factory will do away with the necessity for this when it has once been notified.

Diluted white of an egg and, better yet, serum of blood can be easily filtered under a pressure of from two to three atmospheres. It passes very slowly, it is true, and it requires very great precaution to keep the filtered liquid from getting contaminated or making its exit from the filter. Here is a delicate point. The canula must be fitted to the neck of the apparatus after the latter has been passed through the stove, and at this moment the introduction of a straggling germ is not impossible.

There is a greater interest in being able to thus sterilize all the liquids of the animal economy, even those that do not support heat, without changing molecular structure. The number of pathogenic microbes that it has been found possible to cultivate up to the present is small in comparison with that of the species that have been observed, but that have not yielded to artificial culture. The principal difficulty consists in furnishing to each species a well sterilized nutritive medium, and one that is exactly suited to it. In this respect filtering opens up new horizons to us.

But, on another hand, it must be avowed that this method, with its slowness and the chances of accident that are inseparable from one part of the manipulation, will scarcely be able to supplant the heating method for current use. It will remain limited to the needs of special cultures. Statistic researches, as well as a large number of cultures, will continue to be tributary to the much simpler and more expeditious process of sterilization by heat. It is this method especially that we have endeavored to popularize by simplifying the manual operations so as to render it accessible to every one.—*Dr. H. Fol, in La Nature.*

RASPBERRY LORD BEACONSFIELD.

This raspberry, which was sent to us by Mr. Faulkner, is a chance seedling, produced in his garden at Inkpen, near Hungerford, in 1876. Being of vigorous growth, even in a poor soil of a sandy nature, and also a heavy cropper, it was brought before the Fruit Committee of the Royal Horticultural Society, and obtained a first class certificate in 1883. A large plant of this raspberry was also exhibited at South Kensington this year, which was remarkable for its vigor and prolific habit. It would be an excellent variety for preserving on that account.

The following is a description of the plant by Mr. T. Moore, Chelsea, as given in the *Florist and Pomologist*, January, 1884: "The canes of this raspberry are stout, with a clear smooth nut-brown skin, and reach to the height of 9 feet or more in the sandy soil of Mr. Faulkner's garden. The leaflets are large and pointed, and of a silvery hue beneath. The fruit is produced freely in the axils of the leaves on the summer branches, and is large, roundish, or slightly conical, and of a deep crimson color. The variety is a summer bearer, continuing to produce and ripen its fruit for a considerable period in succession."—*The Gardeners' Chronicle.*

RASPBERRY LORD BEACONSFIELD.

The weeping willow seems to have had a romantic history. The first scion, it is said, was sent from Smyrna in a box of figs to Alexander Pope. General Clinton brought a shoot from Pope's tree to America, in the time of the Revolution, which, passing into the hands of John Parke Curtis, was planted on his estate in Virgina, thus becoming the progenitor of the weeping willow in America.—*The Garden.*

TESTS OF BRICKS.

The results of recent experiments upon red bricks, with a base area of 37·47 square inches each, shows an average stress of about 255,950 lb. when the brick has cracked slightly, or a stress in pounds per square inch of 6,830, or of 439·2 tons per square foot. The stress endured by blue bricks shows a mean of 5,582 lb. per square inch, or 358·9 tons per square foot when cracked slightly. These results appertain to the experiments conducted by Mr. D. Kirkcaldy on bricks manufactured at Mr. J. C. Edwards' brickworks at Ruabon. The Staffordshire blue bricks withstood a stress of 245 tons per square foot before cracking. The samples were bedded between pieces of pine ¾ in. thick. The above results may be regarded as a fair indication of the resistance of bricks to withstand crushing, though the difference between the qualities of two bricks is generally considerable; in the case of the red bricks, the maximum stress in pounds was 446,700, and the minimum 223,500. In the erection of towers and chimney shafts a pressure of much less than that mentioned is considered safe. Bricks resisting 63 tons per super. foot before cracking have been accepted by first-rate authorities, the bricks being made of a mixture of ironstone and blue clay, or some other selected ingredients. At the base of the well-known chimney at St. Rollox, Glasgow, the pressure at the base was calculated to be 6,670 lb. per square foot.

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